THE TEACHING OF BIOLOGY
IN TROPICAL SECONDARY SCHOOLS

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THE TEACHING OF BIOLOGY IN TROPICAL SECONDARY SCHOOLS

by

T. L. GREEN

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GENERAL INTRODUCTION

Scientific discoveries, and their applications in industry, communications, agriculture, medicine and war, have caused great changes in the lives and habits of most of mankind during the last 150 years. Men's ways of thought are not yet accustomed to this change.

Because of the destructive power of some scientific inventions, many men have lost faith in the future of mankind; because of the marvellous power of other scientific inventions to increase the well-being of mankind, many men have expected science to find an answer to all life's problems. Both of these views of science show a misunderstanding of what science is and what scientists can or cannot do. How can such misunderstandings be prevented?

It is not enough to train expert scientists; they are necessary, but it is equally necessary that ordinary folk should know what scientists try to do and how they try to do it. Before they can understand the scientists' work, non-scientists must first learn what science is. For this, a knowledge of scientific facts and principles is not as important as an understanding of science and the methods used in its study. And this understanding of science must become a part of men's everyday life and thought.

Understanding comes through education; but the understanding of science must not remain merely an aim of education: it must become part of it. In schools, isolated courses in one or another aspect of science must be replaced by a view of science as a whole, and of its part in learning.

That is the basis of the project, in this series of books, to advise and help teachers of science. The emphasis is put on methods of teaching and lines of approach to the subject-matter, rather than on the content of a syllabus. It is hoped that, by the use of good methods, the teacher will be able to lead his pupils towards an appreciation of scientific methods and an understanding of science. Through sound education, not only will the few receive the basic training that will fit them for specialization later, but the many will grow up with an intelligent grasp of science and its significance in their social and economic life.

THE SCOPE OF THE SERIES

There are ten volumes in the series, designed specially for science teachers in tropical areas and countries that are not yet highly organized and industrialized, and where the applications of science are not yet apparent in the daily life of all citizens:

I The Teaching of Science in Tropical Primary Schools
II The Teaching of Rural Science in Tropical Primary Schools
III The Teaching of Health Science in Tropical Primary Schools
IV The Teaching of Home Science in Tropical Primary Schools
V The Teaching of Arithmetic in Tropical Primary Schools
VI The Training of Primary School Science Teachers
VII The Teaching of General Science in Tropical Secondary Schools
VIII The Teaching of Physics in Tropical Secondary Schools
IX The Teaching of Chemistry in Tropical Secondary Schools
X The Teaching of Biology in Tropical Secondary Schools

Volume I is concerned with the teaching of science to children in the age-group 6–12 approximately, who are receiving their first formal education. It is designed for students in teacher-training colleges and practising teachers in primary schools. They are shown how to make the most of the children's natural interests.

Volumes II, III and IV also are written mainly for the benefit of the primary school teacher. They treat science at the same level as Volume I, but from different aspects. Thus, Volume II is of especial value to teachers in rural schools: it does not give instruction about the teaching of 'farming' or 'agriculture', but uses these activities to give practical examples of scientific methods and principles in action. Similarly, in Volume III the importance of health is the theme of science teaching. The book will help any teacher, and will be of particular use to those in places where great efforts are being or should be made to raise standards of health. Volume IV associates the teaching of science with life in the home, as the basis of a science course for girls.

Volume V deals with the fundamentals of arithmetic as an essential component of science.

Volume VI is concerned with the training of teachers who are to give the science lessons in Primary Schools, and who, it is hoped, will adopt the methods suggested to them in Volumes I to V.

Volume VII carries the teaching of general science to the earlier years of a secondary course: 4–5 years in the age-group 11–18 approximately. It shows how the work can be regarded both as a course of educational value for its own sake and also as a foundation for further studies. It gives full information on laboratory design and organization, minimum equipment, and maintenance.

Volumes VIII, IX and X discuss the teaching of the three branches of science usually taught in the higher classes of secondary schools. The place and treatment of these subjects in junior work also is considered briefly. The chief aim of these three volumes is to assist the teacher of students who are beginning to specialize, probably with a university career in view, i.e. those who are undertaking 'sixth form' or 'scholarship' or 'first year undergraduate' studies.

THE AIMS OF THE SERIES

Thus, the intention of this series of books may be summarized as follows:

(*a*) To help teachers of science to realize the importance of their work in the community; to help them to guide their pupils to an understanding of the significance of everyday occurrences and experience; and so to educate them to take an intelligent interest in social and economic affairs and to be useful members of their community.

(*b*) To show how science instruction can be organized as a continuous whole, in accordance with modern views of co-ordinated teaching, and how it can be adapted to meet any special requirements of a particular type of school.

(*c*) To suggest a comprehensive scheme of teaching based on sound educational and psychological principles.

(*d*) On the basis of the practical teaching experience of the authors and the general editor and their advisers, to outline the content of science teaching from the Primary to the Pre-University level.

This series originates in the need, so often expressed to the United Nations Educational, Scientific and Cultural Organization, especially by those responsible for education in tropical countries, for more and better science teaching in Primary and Secondary Schools. These educationists share world-wide opinion that training in science is essential to modern education, to the improvement of health and living conditions and the promotion of agriculture and industry. In response to their appeal Unesco conceived the plan and the method of presentation of the series and subsidized the preparation of the ten manuscripts. Responsibility for choosing the authors and the general editor and for the cost of publication was undertaken by the Oxford University Press in agreement with Unesco.

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PREFACE TO VOLUME X

In writing this book I have tried to offer to biology teachers, in tropical countries, as much practical advice as possible on the kinds of topics about which they have asked for help. In collecting ideas and information I have received advice from many quarters and have also been able to call on my own experience as biology teacher, school inspector and university lecturer in England, as Unesco Technical Assistance expert in Ceylon, as Unesco Consultant in India and as Professor of Education in the Universities of Ceylon and Singapore.

Those to whom I am indebted are far too numerous to be mentioned except in a collective manner. I am most grateful to:

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Mr F. Smithies, General Editor of this series of Handbooks, for his help and guidance in the preparation of the manuscript.

To all these and many more in schools and training colleges I wish to express my very grateful thanks for the help so generously given to me.

I hope that those who use this book will find it useful in its practical aspects and of interest, in so far as it enters into theoretical considerations. Where it fails to fulfil its purpose the fault must lie with me and not with those who so generously tried to help me to understand their needs.

T. L. Green

University of Singapore
Singapore, Malaysia.
1964

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CHAPTER I

BIOLOGY AND MAN

In the past, books on educational theory, especially those about methods of teaching, were concerned with *how* to teach a subject rather than with *why* to teach it. As teachers and educationists became more interested in their purposes and aims, more attention was given to this question of why we teach a particular subject. It is important to find the answer to this question, for three reasons:

(*a*) We need to assure ourselves that the subjects we teach have a significance for society, for our community, and for the general conduct of life.

(*b*) It is desirable that the subjects have a meaning for each pupil, as an individual, and not merely as a unit in a mass of people.

(*c*) It is likely that those who know why they do something do it with greater understanding, and so, very probably, with more success than if they lack the knowledge and conviction.

Biology, the individual and society

This book may start, then, by considering the place of biology in education in relation to society, the individual pupil and the teacher. It must be pointed out, however, that while it is easy to divide the matter up in this way, it is an artificial convenience rather than the product of logic. Indeed, not only is it a convenience, but it may be a danger because, by observing the limits between these various aspects, we may too easily overlook their connections. Here it may also be pointed out that, though this book is intended as a practical guide to the teaching of biology, it is impossible to discuss why we should teach the subject without considering theory. All who are in any degree familiar with studies of education are aware of the criticism, so often made, that they are divorced from reality. Reality may be regarded as the practical aspect, but the argument linking reality and education is theoretical. Thus it is essential to pay attention to aspects of our subject which many people think to be purely theoretical. The reasons for doing this may perhaps be summarized in this simple statement: no one can do a job well unless he understands all the processes involved. Those who understand the social and educational significance of biology are likely to teach it with greater success than those who teach just because the subject appears in the syllabus and on the time-table.

Each of these topics, the social and the educational significance of biology, is important. The first two chapters of this book are devoted to them, but, as already pointed out, the nature of the subject-matter and its relationships make some degree of overlapping unavoidable.

The most important and widely embracing biological principle is that of evolution. In the terms of this theory organisms are related to each other in particular ways in time and space. Those of today are the descendants of others, which came from still earlier ones, and these in turn came from the simplest of all forms of life. There must, of course, be an ultimate problem: what is the origin of life itself? To attempt an answer to that question is not the province of such a book as this. The task of the biology teacher must be to take his subject as he finds it and to treat it as it is. This is not an admission that the answer to the question is at present unknown, nor a statement that it can never be answered. It is a practical approach which allows some start to be made. The starting point, then, is that all life, however diversified, has an underlying unity derived from the sharing of a common origin. To accept this at once leads to the admission that Man, because he is part of life, is himself a biological organism in a biological world.

To the scientist there is nothing difficult in this. It is indeed the only statement which he can accept, the only one which makes sense. Man's structural plan, his backbone and limbs, make him a vertebrate. The possession of warm blood, fur and milk-secreting glands, make him a mammal. To believe that Man possesses so many basic characteristics in common with mammals, with vertebrates, with organisms as a whole, and yet is entirely different, is to make difficulties and ignore relations which are accepted for all other organisms.

At the same time Man does differ from other animals. In structural terms the difference is one of degree, rather than of kind. In functional terms it is less easy to decide. Man's physiological functions are similar in kind to those of other animals to which he bears the closest resemblance. It is in regard to psychological functions that the possibility of differences of kind, rather than of degree, arises. This is still more so if philosophical aspects are considered: Man's thoughts, aspirations and beliefs.

The most marked difference between Man and what many believe to be his closest relations is found in brain development. In quantitative terms the brain of Man is in no way essentially different from that of the apes. It is composed of similar materials, it has the same major parts. These parts, however, have been differentially developed, especially in regard to the cerebrum, the centre of the most complex nervous processes. But there is a qualitative difference in terms of mental functions.

It is to this special development of the brain that Man owes what we call his superiority. He has invented tools, speech and writing, and has developed a complex series of mental skills and beliefs which give him a degree of control over his environment greater than that open to any other animal. While all of this is based chiefly upon the development of the brain, other features have played their part. Thus the form of the human hand has led to manual dexterity and the upright posture may also be of importance. Of far greater significance, however, is Man's social life. Man is *the* social animal and his society has become far more complex than that of any other animal. In particular he has developed a store of knowledge and tradition which is carried from generation to generation not merely by memory, but by writing and other records. This cultural tradition is his richest feature.

Many of those who are teaching biology in schools may feel that it is not necessary to be concerned with the truth or otherwise of arguments concerning Man's place in the animal world. Yet it should receive some notice, even if no more than is given to it here, for the following reasons:

(*a*) Whatever the relationship may be, or appear to be, the fact remains that many of Man's problems, both individual and social, are biological problems. They can be stated, defined, studied, understood and solved or overcome in biological terms, and in many cases in such terms only.

(*b*) One characteristic of the adolescent is a concern with philosophical problems, especially those relating to the meaning, purpose and design of life, the nature of matter and the problems of value. Questionings about Man inevitably rise in the minds of young people. The task of seeking every means of satisfying these ponderings must be accepted by teachers. One step in this task is to present all forms of knowledge which seem relevant.

(*c*) Speculation and pronouncement about the nature of Man is inherent in religious belief. Youth, pondering upon religion, may find a seeming conflict with science. Similarly there may develop apparent conflicts between ideas derived from the East and the West. The nature of these conflicts cannot be entered into here, but the teacher should not only be ready for them, but should have at his command everything that may help in resolving or reducing them.

If it is accepted, either as a truth or as a convenient working hypothesis, that Man can be looked upon as an organism, and therefore subject to the laws of the organic world, it becomes possible to explore in greater detail his place in nature. There are two reasons why this should be done: first to gain understanding in a philosophical sense, and secondly to seek lines which may provide guidance in the development of a theoretical basis for biological education.

Man as an organism

In terms of both structure and function, that is from anatomical and physiological viewpoints, Man may be regarded as an animal. In both spheres, comparative studies and an evolutionary concept of relationships between animals have helped to elucidate knowledge of Man. In particular, experimental work upon individual animals, or upon populations of animals, has made possible investigations which could have been done less easily, if at all, upon Man. Knowledge has thus been extended in many ways. While such knowledge is important in a purely academic way, in that it helps to satisfy the never-ending search for truth, it also has other values.

On the most elementary plane it could, and should, make it possible for everyone to have some understanding of how his or her body works. As life becomes more mechanized the need for more and more people to have an elementary understanding of simple mechanisms is made clearer. Without some such understanding, the telephone and motor-car, for example, are likely to be misused. Thus they may well become a danger. The motor vehicle has already become one of the most lethal weapons known to man, and, to some extent, this is because ignorance leads to misuse. By analogy the human mechanism may be better used by those who have some understanding of it. Health, for example, within the operation of such limiting factors as economics and genetics, is to a considerable extent dependent upon the use of the body. Lack of exercise, of sunlight, fresh air or rest, all have adverse effects which are often unrealized both as results and causes. Biological knowledge may be a factor in improving the habits of living, providing it is used appropriately, a point to which attention will be given in the next chapter.

While this argument is true for the highly organized urban areas of industrial countries, it is no less true for the most rural areas of the least developed countries. Indeed, in the latter the possibilities for relating biological knowledge to living are greater, and its potential value is greater. Over vast areas of the world the health of millions of people is poor because they lack the knowledge and attitudes which may be derived from a study of biology. This is perhaps seen most clearly in connection with intestinal and other parasites which cause serious ill-health and often death. Yet the application of even elementary biological knowledge can profoundly alter and improve the situation, to the benefit of both individual and society.

There is another aspect of this point which, elementary though it is, seldom receives notice. First, let it be noted that several of the practices of villagers in under-developed areas are not, as critics so often say, based upon mere superstition. Today they may be said to result from ignorance, but at their inception they were probably derived from experience and such knowledge as was available. Yet it is also true that fear has some part in human response, not only in unsophisticated societies, but even in highly developed cities. Fear often prevents people from seeking medical advice until it is too late. Fear often causes them to refuse surgical treatment and undoubtedly plays some part in the delay of recovery from it.

It is, however, on the more advanced planes that the significance of adopting a biological view about Man is seen. However great our achievements in transportation, communications and the like, the application of biological knowledge to the problems of living is a basis without which all other advances are relatively valueless. It is to the achievements of biologists, working with, or as, medical men, that we owe the control of disease, developed in the twentieth century. It may be true that there is still much to do, but it is equally true that much has been done. On the one hand there is the curative work, dependent upon success in the fields of biochemistry and micro-biology. On the other there is the preventive work in which disease is attacked, before it becomes operative, by the application of biological controls to disease vectors. In the fields of surgery there are new drugs to make the work of the surgeon easier, to reduce the shock effect upon the patient, and thus to hasten recovery and increase the survival rate.

Public health services, though they are classed as medical services, are essentially biological in nature. They too have both curative and preventive aspects. It is perhaps the latter which is the more important and its achievements are largely due to the applications of biology. On the one hand, use is made of knowledge of the biological conditions which affect man as an organism, on the other, of knowledge concerning the factors which affect the organisms that attack him.

Water and food are primary needs. Though the supply of water is a problem for the civil engineer, the control of the water supplied falls to the scientist. As chemist he ensures its freedom from noxious substances, as biologist he controls its organismal content. The significance of biological knowledge in relation to food is perhaps greater than that of any other field of applied biology. The basic problem is simple: the increasing of food supplies to keep pace with the increases of the world's population. There is, of course, an economic aspect, and this has sometimes placed narrow, sectional interests before those of society as a whole. This has led to local food shortages which were not due to scarcity in total terms, but to unequal distribution. In general, however, the main task has been that of 'making two ears of corn grow where only one grew before'.

The contributions made by biologists and their associated workers, especially the biochemists, to the world's food problems are of enormous importance and extent. The breeder has selected and improved plant and animal stocks by the application of genetic knowledge. In this way certain 'strains' have been developed which are, as it were, specialists. Thus there are some sheep which provide wool, others meat, and the breeder is seeking a strain which will give maximum yields of both. There are some cows bred for milk, others for meat. There are varieties of wheat resistant to rust disease, varieties able to withstand low temperatures and short days and, of particular importance in tropical areas, there are rice strains which are suited to various conditions and which give maximum yields under each. The breeder has done more than select and improve, he has invented new things, by crossing, hybrid grafting and the like.

The biochemist and botanist have studied the chemical needs of plants and the extent to which these are met in local soils. Fertilizers have been developed to make good the deficiencies, thus improving crops. The use of manures has gone even further: certain types have a selective action and encourage some plants but kill others. Another aspect of this work, in which biologist and biochemist have collaborated to improve food supplies, is in connection with the development and use of insecticides, which protect plant life by killing parasites.

Considerable as the achievements of the biologist have been, it seems clear that society is likely to become even more indebted to him in the future. Food canning, dehydrated foods and 'deep-freeze' are probably only the beginning in tackling the problems of food storage and preservation. Yields are being increased continuously, and even better breeding stocks of both animals and plants are being developed. One of the most significant moves is the increasing attention devoted to the food resources of the sea. At first this was concerned with improving methods of catching fish; next came the problem of controlling the catch, so that the immature could be allowed to survive to grow larger. Now the question of 'farming' the sea is in hand. The need for food has necessitated food production, and this has made the biologist turn to the study of the economic aspect of his problems.

The biology of Man: social biology

The decision that Man is an organism raises the possibility of developing a special branch of biology devoted to the study of Man. Many of the problems which at once spring to mind may be listed under existing sciences, such as medicine, anatomy and physiology. There is however a place for a new development, a human biology, which may, and indeed does, deal with problems of a different kind.

One such problem concerns the growth of population. To many people this may appear to be a matter only for those who take a census, or work as actuarial statisticians for insurance companies. It is true that their work supplies information about changes in the population, the rate of such changes and their effect upon the composition of the population. Such knowledge is important and makes possible an estimation of population in the future. There are, however, other aspects to which attention should be directed.

It is important, for example, to make a study of the relationships and characteristics of different peoples. The world has passed through an upheaval in which the theory of a 'master race' played no little part. It therefore seems essential for us to know not merely the limitations (if any) of different peoples, but also to study their potentialities. Such work, though it may well become psychological, has a biological origin.

Human genetics, though its results cannot be applied very directly, is another interesting and important study to which biologists give attention. Its results are specially relevant to the study of interrelationships between different groups. They also have value with regard to certain problems of disease and defect.

An aspect of human biology which has received considerable notice recently is that of sex, one of the fields in which new knowledge has been applied directly to bring about changes of sex, and indirectly to the better understanding of behaviour problems.

It may also be noted that, especially among sociologists, human society as a whole is sometimes considered as an organism, individuals being its 'cells'. While such an interpretation has many dangers, it at least emphasizes the significance of biology in relation to Man.

Biology and education

The significance of biology for society should be reflected in the educational sphere. The subject can only be of value if it is socially orientated. Unfortunately, there is too often a separation between what society needs in the field of education and what it provides. What is provided must be considered along two lines, in terms of extent and in terms of content, i.e. Do enough children learn enough about biology and is the right sort of biology taught? The dangers of generalization are too well known to need stressing here, but they are risks which must be accepted. In order to demonstrate the potentialities of biology we must know something of the limitations of the subject as taught in many schools today.

In many areas biology has already played a part in education. However, the critic who assesses such biological education in social terms is likely to find that it fails, for various reasons, to achieve its potential value. Without attempting to make a complete list of the weaknesses, and without suggesting that all biological education is inappropriate or that all the shortcomings exist everywhere, a brief survey may nevertheless be of some use.

In general the teaching of biology tends to be restricted. For instance, it is less common than physics or mathematics in the curriculum of the secondary school. (The term biology is used here in its generic sense; it includes botany and zoology as well as the subject of 'biology' as laid down in examination syllabuses.) In primary education it is similarly neglected, even in the guise of nature study.

The need for a laboratory in the teaching of physics and chemistry is usually realized, but this is not always so in biology. Though it may be possible to share another science laboratory, or even to make use of an ordinary class-room, the need for premises, properly equipped for biology, must be stressed. However, where there is no special laboratory, sharing and adaptation should be chosen in preference to giving up the subject. Sharing and adaptation, however, have their dangers, as seen, for example, in the fate which tends to overtake the biological part of the 'general science' syllabus.

There is a shortage of teachers qualified to teach biology. This appears to be due partly to the fact that, at advanced levels in college and university, facilities for biological education are also somewhat restricted; and partly due to the fact that the subject may seem less attractive as a vocation than other sciences.

In addition to the limitations in the extent of biological education there may be deficiencies in its nature. The tendency to emphasize the separate subjects of botany and zoology, rather than to seek a wider understanding, has already been noted. Related to this, and perhaps because of it, are other weaknesses which should also be mentioned.

There is great emphasis on the study of structure, rather than of function. Thus pupils often memorize facts of anatomy and morphology, but have little understanding of physiology. The need to understand structure as a basis for the understanding of function is not to be denied, but the former without the latter has not much social value. This attitude, this stressing of the descriptive study of structure rather than the analytical study of function, is seen also in the relative emphasis upon systematics at the expense of ecology. Most of all, of course, it is seen in the study of dead specimens rather than living organisms.

Another widespread and unfortunate characteristic of school biology is the neglect of its interrelationships with other subjects of the curriculum. There is little attempt at integration. Thus, it is not uncommon to find pupils, and sometimes teachers, who can think of botany, zoology and biology only as three distinct subjects. The link between the biological sciences, physics and chemistry gets too little attention. Even general science tends in fact to be three subjects whose only bond is that they appear within the covers of a single book. On looking further afield, the neglected opportunities to weld knowledge into a unity become even more apparent. Thus in many countries, dependent throughout history upon a rural economy, it is common to find that rural science has no place in education. Even where 'agriculture' appears in the time-table it tends to be a rigid training course, lacking reference to the principles of biology upon which it should be based.

Nor are the methods of teaching, so far as they can be separated from its content, any more suited to make the best use of biological science. The tradition of verbal learning and memorizing has, in some places, led to a formal and abstract approach to science teaching as a whole, at the expense of practical work in field and laboratory. 'Knowing' has become confused with 'remembering', at the expense of 'understanding'. A similar situation has come about for another reason: the too hasty adoption of teaching methods and attitudes developed in countries where there are much greater opportunities of informal education. In such countries children often have access to many materials and experiences, the freedom to experiment and explore, and a wide background for a formal procedure in school. The transfer of such methods to situations in which they have no backing from experimental opportunity is unfortunate, but all too common.

Thus biology tends to be learned too much from books and blackboard, and too little from specimens (especially living ones) or life situations. Field-work is rare and tends to be cursory and merely observational, lacking in analytical recording and experimentation. The organization of field-work is often difficult, not only because of local culture patterns. Such conditions ought to be a challenge to the use of the school garden in the service of biology, but this, too, is often neglected. Nor is there any extensive use of aquaria, vivaria and museums.

It will be seen that the crux of the matter lies in the lack of emphasis upon the social significance of biology. Despite what has been said, though very briefly, about the contributions of biological knowledge to human welfare, this aspect receives little attention in schools. Yet it should be clear that there is much to be gained from a more appropriate development of biology. Comment has already been made upon some of the causes of this situation, and many people are aware of the difficulties which education has to face in some regions. What must be realized more clearly is that it is only by *more suitable education* that these conditions can be overcome. To achieve this it appears desirable, indeed essential, that teachers should have a wider understanding of sociological factors. These are many, complex and varied. Not all of them are known, because so little attention has been given to the social aspects of education.

Religious beliefs undoubtedly exert a profound effect upon education. It is certain that they influence biological education. Thus, in Buddhist societies, botany tends to be better served in the schools than zoology, a fact which may be connected with the belief in cyclic reincarnation and that the human spirit may be re-born in an animal. Other religions and religious beliefs lead to similar difficulties. They must be respected, but nevertheless they confront the teacher of biology with a very real problem, and sometimes they tend to prevent the acceptance and growth of scientific knowledge. This is no place for a full discussion of this topic, but every teacher should think about the problem, and about other attitudes arising from religious beliefs.

Another example is the attitude towards social welfare work of various kinds. In some countries there has grown up, over a long period of time, a deep public concern about the general welfare of children. Started by individuals, and partly due to religious attitudes and finally appearing as a necessity in view of a falling birth-rate, the development of ever better welfare services in relation to childhood is an established aim. Children are spoken of as 'the citizens of the future' or the 'nation's most valuable asset', and society has accepted a responsibility for them which, in some ways, is more than an ordinary family can hope to do. These attitudes have helped to develop an interest in the problems of social biology and thus to give it a bigger place in education, especially at the higher levels. In other areas of the world there is little evidence of a similar concern for childhood. The birth-rate is high, so that children have no scarcity value, and there is no drive towards taking special care of children. The demographic pattern does not suggest that the future of the people may be in danger. Added to this there is, in some cases, a belief that the life of each individual is patterned by the past, in the sense that each individual reaps suffering or reward in keeping with his behaviour in previous lives. Such beliefs make the teaching of biology difficult.

In the face of this and similar beliefs, and in the absence of any apparent threat to future numbers, many peoples feel no need to develop welfare services or training courses in child care, in which social biology plays an important part.

Nor has the threat of a large increase in the population of certain areas so far made many governments try to apply biological knowledge to social ends on any large scale. Despite the fact that increase in population is far ahead of increase in food production, attempts made to develop understanding of the need for some sort of control seem to meet with little success. As is the case elsewhere, though not always for the same reasons, this also is often considered as a field in which there should be no interference with the individual. Perhaps this is partly due to attitudes towards sex in social terms. In many, though by no means all of these areas, the male is 'superior'. This is seen in the general attitude towards women, her slender claims to consideration or protection (as compared with women in some other countries) and her lack of economic freedom. There are differences of culture. As teachers, we have to admit them, even without any attempt at evaluation. We should not say, for example, that Asia's practices are more or less worthy than those of Europe. We must each try to look at the facts as they are and make up our minds about the position of biology in education. We should not fail to realize the social significance of welfare services and the kinds of knowledge which contribute to their development.

There is also, sometimes, an unwillingness to accept anything likely to upset the delicate relationships which time and experience have developed in society. Thus the social value of biology is partly unrealized and partly refused. As teachers we must face this situation and study it.

Conservative attitudes are often too readily condemned as reactionary by those who, wishing to transfer their own culture patterns to another society, overlook the importance of the time-factor in the processes of change. The organization of industrial life in Europe and America has, for example, brought about changes in attitudes within the family, and even in family social structure. These have developed over a long period. The introduction of industrialization in any country involves similar readjustments based upon social changes. Many of those who seek to avoid these changes do so in the belief that they will destroy much which is of value. Such a belief is not merely reactionary. It may be an attempt to avoid conflict. It may even be an attempt to avoid the chaos which can result from rapid social changes.

The essence of the problem, however, seems to lie in accepting possible danger, and in realizing that, because social change must take place in a world becoming smaller as a result of our control of time and distance (and hence of communication and travel), the danger must be minimized. It is here, as an agent which can play a part in achieving cultural change by avoiding social conflict, that social biology has so much to offer.

The contribution of social biology

Biology, treated as a social agent, should be able to contribute much of value in a changing social world. This contribution may be put under three headings:

(*a*) Biology, properly taught and having a social aim consciously used as the basis of content and method, may give direction to the whole of education, and thus to the life of the individual, family and community. In countries where agriculture, though often lacking modern machinery and methods, is of great importance, and where ill-health is common, the development of new attitudes and the presentation of new knowledge through biological education is essential. In agriculture, materials and methods may be improved, giving more and better produce, and thus improving the economy of the people even without increased expenditure. More food in itself has an effect upon health, but when joined to greater knowledge of better diet and a deeper concern for hygienic practices, it makes social gain even greater. Again it should be noted that greater expenditure of money is not necessary. More sanitary habits, avoidance of infection, and the purification of water, cost very little.

It must be admitted that gains in one direction may bring problems in another! The success already gained through 'fundamental education' and 'health education' has done much to prevent ill-health. The rise in the survival rate has made even clearer and more important the problem of how to increase food production. This, however, should not lead to criticism of education, but to its extension. The need for more food is another challenge to use education to improve production.

(*b*) There should follow from suitable biological education a greater understanding of scientific method. This is not to be sought in academic terms, but in attitudes. At present a villager tends to say 'Yes' to the agricultural adviser, the health visitor or the sanitary inspector. But often he goes on in the same old way, seeking better crops by 'magic' or better health through 'ju-ju'. The foundations for a change of outlook must be laid in school life.

(*c*) We must seek from social biology a foundation for new attitudes of responsibility, outlooks not necessarily the same as those mentioned above, but concerned particularly with inter-personal relationships. One of the great truths of biology, only perhaps to be seen from *functional* studies, is that of mutual interdependence, the basis of social responsibility. Man has learned the art of living in communities, of being interdependent, only slowly and as the result of lengthy experience. Nowhere can it be said that there cannot be improvement. In many countries, especially those where new contacts are quickly changing social conditions and breaking down old traditions (without building up new ones), quarrels and tension affect inter-personal relationships more and more. Often the result is a lowering of social responsibility, the old and familiar ideas having been destroyed. In such conditions we may well be able to use social biology as a means of starting to rebuild what 'progress' has destroyed—faith in, dependence on and co-operation with fellow men.

What kind of biology?

If biology is to contribute as it could to social affairs it must be social biology, the study of those principles of biology which are relevant to social needs and issues. This does not mean that all the content of the biology as now taught has to be sacrificed. Social biology, or a socialized biology, must include much which is already familiar. From this should be developed the principles to be applied to social problems. The task of the educationist must be to change the approach, to emphasize the importance to society of the study of biology. Biological knowledge must be used in direct application to society and to provide skills and attitudes which are relevant to social living. Thus the community may be used as material for biological study.

There are many who feel that this need for a socialized biology is already fulfilled because, as they point out, the curriculum stresses the need to apply biological ideas to human affairs, and textbooks sometimes make an attempt to do so. On the other hand, those who are deeply concerned to use biological education for a social purpose know that the existing practices are in general inadequate, and that it is only by proceeding along lines such as those proposed in this book that their aims can be fulfilled.

No one can apply biological principles to social problems unless he has a grounding in the principles themselves. That fact alone makes it essential for biological education to be concerned with principles, and not merely with a mass of details. Nor can we expect pupils and young students to make the transference from purely biological to social thinking without aid and practice. Thus we should continue the study of biological science in schools as a pure science, laying foundations for a possible career in biology or medicine, etc., but also develop a new aspect, social biology. This must be a biological study of society.

If this approach, by no means common even in countries where biological education has a long history, and in some places entirely new, is to be effective, it is necessary to ensure from the start that it is realistic. It will be fruitless if it is just another theoretical study, to be learnt only in the class-room and from textbooks. It must be concerned with the society, the local community and the school population. These must be used as the raw material of investigation. There cannot be experimentation in the same way as with fruit flies or tadpoles, but there can be the collecting of original data, the analysis of existing data (such as local health records), etc. Only by using the community in this way can social biology have meaning for the pupil. Some examples of ways in which this may be done are described later in this book.

CHAPTER II

BIOLOGY IN THE SCHOOL CURRICULUM

Having suggested in the foregoing argument what may be called a social need for biology in education, it is necessary to examine the question as to how far there is an educational argument to be considered. The two questions overlap of course, but it is necessary to look into the matter in this way also, in order that teachers may be familiar with certain other ideas which should influence their teaching.

Science in education

There are many people who see in the further development of science a potential threat to their way of life. This is particularly so in countries where political independence has been recently achieved, bringing with it a natural and valuable resurgence of national sentiment. The danger lies in the too ready belief that science belongs to the heavily industrialized countries, and must therefore be antagonistic to the spirit of countries which are basically rural and have little organized industry beyond that of a home or cottage type. Science is by no means the exclusive product of 'the West'. From other countries, through long periods of time, there have been leading contributions to both the theoretical and practical aspects of science. There were many reasons for the growth and rapid development of industrialization in particular areas, but these were largely due to accidents of time and place rather than to essential differences in the nature of mankind. One by one, countries which have, so far, been little industrialized, are accepting this new form of socio-economic organization, and the danger lies, not in the new organization, but in the too rapid adoption of social processes, which destroy traditional ways of living without giving time for adjustment to the new conditions.

It must also be pointed out that there is little opportunity for choice. The modern world is here with us. It is a world made smaller by our ever-increasing control of time and space, and our ever greater degree of economic interdependence. It is not possible to put the clock back without suffering dangers of a kind similar to those which arise from putting it forward too quickly. It is no longer possible to choose or refuse science, since the continuance of life is bound up with the present and potential achievements of science. Survival may indeed be threatened by the applications of science, but it would be equally or even more certainly threatened by failure to accept the applications of science. The task facing society is to ensure that use is made of science along socially appropriate lines. One step towards doing this is through giving to science its rightful place in education. To do this depends to some extent on the recognition by teachers of what this place is. Looking at the position in a broad way, it appears that the claims of science may be presented as follows:

(*a*) Life depends more and more upon the applications of science, so that more and more people are being brought into direct contact with science. In the 'advanced' countries this is obvious, but even in the less advanced countries it is equally true. In brief, our patterns of living, however diverse, are becoming ever more technological.

(*b*) Technology needs a continuous supply of technicians. Long experience has built up a tradition among craftsmen in manual societies which have often become comparatively complex. But tradition alone cannot provide the more specialized technical workers required in mechanized societies. These technicians have to be trained in a different way, under a newer system, in which science must play a part.

(*c*) Scientific objects and processes have today become a commonplace almost everywhere. Science is part of the culture pattern of the modern world. To make the most of this modern world we need not only the scientific knowledge of the experts, but the possession by all men of certain attitudes towards science. Science and its cultural derivatives necessitate new attitudes towards time and distance, towards people in other countries, towards entertainment, work, family planning and even the modes and materials of eating and drinking.

(*d*) Science has an increasing significance in relation to government and administration. At the highest level the politician and planner have to depend upon scientific evidence and advice, and at the lowest level village programmes depend upon the uses of science. Thus at both levels there is a need for some degree of understanding of science.

(*e*) Science, at its different levels, has a natural interest for mankind at all ages and stages. In the primitive societies of the past, and everywhere today, Man showed, and continues to show, his interest in science by his ideas and in his attempts to control his environment. Science has great interest for children of all nations. Thus, science should have a significant place in education not only because of its content, but also because it arouses a degree of interest which often leads to effort.

(*f*) It is often claimed that an understanding of scientific method is obtained through school science, and that this is important in adult life. While it is true that scientific method may be learned from scientific education, it is important to notice two points. Firstly, that pupils can, and too often do, learn science, yet fail to learn about scientific method. Secondly, that an understanding of scientific method may be obtained from other studies than science itself.

The second of these two points is often overlooked because of a tendency to misunderstand the nature of scientific method. This is usually thought of as a way of doing things, so that the boy who measures in hundredths is thought to be 'more scientific' than one who measures only in tenths. The crucial point however is concerned with understanding. To accept hundredths as precise units just because this is the value stamped on the weight is by no means scientific. But to be cautious, to compare the tenths with each other and check their relative values, and so to obtain an index or coefficient which may be used to make an observed value a closer approximation to the truth, and to know that it is only an approximation, is to be scientific in thought.

It is a common error to confuse doing with thinking. Moreover, it is often assumed that the physical and chemical sciences provide the best training in scientific method, because they are the 'exact sciences', while biological sciences are 'inexact'. This appears to be an extension of the confusion about doing and thinking. There is also a failure to realize that a great deal of the science which is taught in schools is concerned with first approximations, not with absolute values. What is most needed is caution in thinking, a readiness to reserve judgment and to modify a point of view in the light of new knowledge. To be able to distinguish between truth and surmise, between fact and hypothesis, and to realize that tradition may be wrong though the new is not necessarily right—these are the desirable outcomes of a scientific education. They are modes of thought, not methods of doing.

The development of scientific education, based as it has been on the ideas already mentioned, has tended to an emphasis upon physics and chemistry, which followed mathematics, though much later. As the shortcomings of these ideas became more apparent, the claims of other sciences, particularly biology, began to receive attention. There are those who wish to see astronomy and geology (to take two examples) included in the school curriculum, apart from other forms of science. The inevitable answer is that the school day is too short. In seeking to choose those sciences which would be of most worth there arose the idea of 'general science', a study of the major principles of the great sciences. The appeal of this lies in its unification of ideas. The presentation of science as a whole, with its many branches seen in relation to each other, deriving from and contributing to each other's growth, avoids the breaking down of knowledge into a series of artificial compartments. Unfortunately this breadth of vision tends also to be the quality which makes the teaching of general science difficult. There are too few teachers with a sufficiently broad training, largely as a result of the narrowly specialized courses at college and graduate level. This situation may be changed, however, as the universities are today becoming more concerned about the social significance of their own work.

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Biology in relation to scientific education

Biology plays a part in education for two reasons: because of its own significance and because it is part of the major field of science itself. The first has been discussed in Chapter I, and the claims of science in general have been considered briefly in the last section. It is now desirable to examine the claims of biology as a science. Three points appear to be important:

(*a*) Biology shares many of the characteristics of other sciences, using data and practical procedures and having applications which are shared in common. Thus, if sciences as such can make a contribution to society, so can biology.

(*b*) Like science, as a whole, biology has a significance for education. It offers knowledge of direct value to the growing individual, contributing to the development of acceptable attitudes and providing deep interests.

(*c*) Biology appears to have a special significance in connection with training in scientific method. Experiment and experience, particularly in the field of 'operational research', has shown that in situations which are not open to exact control (or to the degree of control possible in the fields of physics and chemistry) the biologist, used to dealing with unpredictable and uncontrollable phenomena, is particularly successful. The events of life itself are largely linked up with biological phenomena, and few social processes, even of the most humble kind, are open to prediction or control. Thus it appears that biology may help the individual to become skilled in handling particular data and situations for which training in the exact sciences may be less useful.

Although the necessity for some grasp of scientific method is accepted as an explicit aim in the highly developed culture patterns of Europe and America, it is doubtful if this is so in some other parts of the world. Yet the need for it is just as great and indeed may well be greater. In some countries tradition has provided almost the only guide to action. Now, under the influence of new contacts, tradition is breaking down, so that the individual, having lost his familiar frame of reference, is all too ready to listen to anyone who appears able to guide him. Among the would-be guides are those whose ends may be well-intentioned and selfless, or selfish, proselytizing and political. In such a situation the ability to think clearly in the face of complex variables is not lightly to be dismissed. Without it there is a growing danger that specious argument and illusory promise will endanger democratic ideals and social progress.

It is not common for the teacher of biology to think of the potential contribution of his subject in this way, but it is in this direct use of biology as a socializing agent that its value lies. The value is derived from both the informational aspect and the attitudes which should develop from the study of social biology. If human behaviour depended only upon a rational foundation, it is possible that information might be thought of as the major reward of education. Common experience, however, makes it clear that behaviour does not depend only upon knowledge and rational thought. It depends also upon beliefs, attitudes and superstitions. Here biology should play its part. Like all science and in common with other subjects, biology can contribute to knowledge and scientific method, but by its nature may go further and make a greater contribution than any other form of science teaching.

The interrelationships of biology

From the educational point of view one of the chief values of biological science is that it brings together the methods and results of a number of other sciences. Biology draws on mathematics, physics, chemistry and geology, and acts as an integrating agent. Thus, by using these sciences, or some of them, in relation to each other, the pupil obtains not only an understanding of their relationships, but a greater understanding of each. He learns, as it were, the same subject, from more than one viewpoint. This is important because the unavoidable divisions of knowledge, which are imposed by time-table, curriculum and other contingencies, tend to obscure the fact that science is a whole body of knowledge, and not a 'collection of bits and pieces'.

Biology of course has a unity of its own, which must not be overlooked. Though botany is concerned with plants and zoology with animals, the two share a number of common principles. These must be made clear, as must the relationship between biology and other subjects. The first step is to ensure that teachers themselves are aware of these relationships and of this fundamental unity. It is thus necessary to consider two topics, the major principles of biology itself and the interrelations of biology with other subjects.

The major biological principles. Knowledge may be looked on as having two components: details and generalizations. By the collection of separate facts and observations, a body of details is built up. This may ultimately be reduced, perhaps, to a single statement, which embodies the significance of them all. This is a generalization; if, in the future, all new facts of the same kind fall within it, then it may be regarded as a universal truth. If new facts, which do not fit into it, are found, then the generalization must be altered to embrace these too. Thus generalizations and universals always tend to be hypothetical in nature. The scientist accepts them as true in the light of what is known. If new material shows them to be inadequate, then he modifies his theory. He works, as it were, in an atmosphere of suspended judgment. When a long-accepted idea is proved to be wrong, he does not feel that some special loyalty drives him to hold on and defend it; his concern is with truth. These statements are themselves generalizations. Indeed experience has shown that loyalty to a 'scientific' or political idea may cause the scientist to abandon the impersonal and objective attitude he should preserve.

It is in suspended judgment and the use of details to build universals that the value of scientific method lies. Thus, in teaching the aim should be to use details as a basis for building universals. The study of a fish, frog and rabbit should not only provide detailed knowledge of the structure of each: it should also result in a concept of 'the vertebrate'. The study of various plants should build up a picture of 'the plant' as distinct from 'the animal'.

It is regrettable that many textbooks are devoted to details, with little or no attention to principles. Among teachers there are those who fail to realize that biology can be reduced to a number of broad statements, generalizations giving the essence of the subject. The pupil who does not appreciate the universals is failing to get from biology all that it can offer. He may know much about the structure and life history of micro-organisms and about the factors which affect them. These are details. If he has failed to build them into a universal he will never realize that boiling handkerchiefs has a significance which is different from merely washing them 'clean'. The making of generalizations from details is a mark of ability, so that the most able pupils can do it most readily. All pupils however are able to learn how to do it, if they are taught. Thus the teacher himself needs to have a clear picture of the major principles of biology. What are these principles?

At the very simplest it may be said of living things that 'they are born, they reproduce and they die'. This however is open to question—to be born suggests mammalian birth, which is not universal. Thus a more precise list is needed, such as that shown here.*

Living organisms

1. Come into the world
2. Feed
3. Breathe
4. Grow
5. Get things done
6. Become parents
7. Take care of their young
8. Depend upon their surroundings

This simple analysis gives a more complete picture of what organisms are, a general picture of life, but it leaves out a number of very important principles, because it was not intended to be all-inclusive. The problem of deciding which major principles of biology should be considered as the fundamental content of the biological curriculum in relation to the needs of the average person was considered by a group of educators in the U.S.A.* As a result, a list of these principles was drawn up.

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* Proposed, as an elementary statement, by Professor Lauwerys of London University.

A list of the principles of biology

(1) Energy cannot be created or destroyed, but merely transformed from one form to another.
  (*a*) Energy is supplied to organisms by oxidation processes.
  (*b*) A continual food supply is required to provide energy.
  (*c*) Because protoplasm contains protein this must be supplied in the food sources.
  (*d*) Food substances must not contain deleterious matter.
  (*e*) Oxidations result in waste metabolites which must be removed.
(2) The ultimate source of energy of living things is sunlight.
(3) Micro-organisms are the immediate causes of some diseases.
  (*a*) Transfer of micro-organisms can be prevented.
  (*b*) Microbes exhibit differential survival capacities.
(4) All organisms must be adapted to the environmental factors in order to survive in the struggle for existence.
  (*a*) There are complex interrelationships between organisms.
  (*b*) Man must protect those plants and animals which have been domesticated to ensure their survival.
(5) All life comes from previously existing life and reproduces its own kind.
  (*a*) The new organism starts life as a fertilized egg.
  (*b*) Unit characters are inherited and determined by genes.
  (*c*) There is a mechanism for distribution of characters.
  (*d*) Some characters depend upon more than one gene.

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* American National Society for the Study of Education.

  (*e*) Proximity of genes leads to linkage.
  (*f*) Crossing over may break up link-associations.

(6) Animals and plants are not distributed at random, but are found in definite zones and societies.
  (*a*) These zones are separated on the large scale by geographical barriers.
  (*b*) Local societies depend upon micro-factors of climate and food.

(7) Food, oxygen and certain optimal conditions of temperatures, moisture and light are essential to the life of most living things. (Undesirable organisms are often destroyed by controlling one of these factors.)

(8) The cell is the structural and physiological unit in all organisms.

(9) The more complex organisms have been derived by natural processes from simpler ones, these in turn from still simpler, and so on back to the first living form.

Another analysis by an American educator* is of interest because it narrowly defines each of the principles and builds them up into a unified whole. This is shown below.

Fundamental biological principles

(1) Living things differ from non-living things in that they possess a definite cellular structure—the principle of *cellular organization*.

(2) There is a constant building up and tearing down within the body of every living organism—the principle of *metabolism*.

(3) Living things grow from within through changing food into living protoplasm and new cell walls—the principle of *growth*.

(4) Living things must adapt themselves to the conditions of their environment if they are to survive—the principle of *adaptation or ecology*.

(5) The varying success of organisms in adapting themselves to various environmental conditions has given rise to

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* Preston, 1936.

topographical, geographical and climatic groupings—the principle of *distribution*.

(6) All living things have the power to produce new organisms similar to themselves—the principle of *reproduction*.

(7) Offspring inherit parental characteristics—the principle of *heredity*.

(8) Scientists generally believe that all forms of life on earth today have developed through the ages by gradual changes influenced by both heredity and environment, as the progeny of some simple primordial organisms—the principle of *evolution*.

(9) Organisms past and present can be grouped according to one 'family tree' which shows what is believed to be their hereditary or evolutionary relationships—the principle of *classification*.

(10) The interdependence and interrelations of living things give rise to a natural equilibrium, the temporary disturbance of which takes the form of epidemics—the principle of *balance in nature*.

(11) All living things react to external stimuli—the principle of *behaviour*.

It will be seen that both these lists give a picture of what we may call the contents of biology, but when they are compared with the contents of the average school textbook in biology several differences appear.

The first list was described by the committee which made it as being based upon the 'life needs of the average man'. This is a direct statement that the syllabus should be related to social needs and not be a mere reflection of academic or logical demands. It may also be seen that this list does not distinguish between plants and animals, that it places an emphasis upon function as distinct from the structural and systematic aspects of the subject. The second list shows similar features. Taken together they make it clear that biological knowledge may be condensed into a series of major principles built up from a vast mass of details.

It must be the teacher's task to understand the relationship of these details and principles, and to help his pupils to do so. This not only makes learning easier, but increases understanding. It helps pupils to carry over biological attitudes into life situations, and to apply them where possible in a social sphere. It also lays a foundation for understanding the relationship and significance of biology to other subjects in the curriculum.

The relation between biology and other subjects. The complaint that pupils live in an atmosphere of water-tight divisions between the various school subjects is, to some extent, the reflection of a similar situation among teachers. The need to specialize plays an important part in this, but the situation is not unavoidable. One step towards overcoming the difficulty is to help teachers themselves to be more aware of the various interrelations. This knowledge they can then use in various ways to achieve integration or correlation between subjects.

Biological science has a particularly important function to fulfil in the correlation of various subjects, though this should not be stretched too far. An emphasis upon its principles, and attention to the way in which these are built up from details, is an essential first step, so that pupils are aware of the possibility of a biological event being more than a single isolated item. They must be taught to think of biology as a wide field of science, which extends into other sciences, from which it borrows and to which it also gives. Teaching should be as practical as possible, offering opportunity for activities and contacts with social situations outside the class-room.

School gardening has an obvious link with biology, yet it is seldom well developed. School gardening has too often been thought of only in terms of crop production. Essential though they may be, campaigns such as 'Dig for Victory' tend to limit rather than expand the conception of biological science. Biological principles exist in the world of nature, not merely in the science room and laboratory; the garden should thus be an outdoor laboratory where experiments can be conducted on the grand scale. There is no reason why this should reduce the productivity of the garden, but, in the last resort, it should be clear that the function of the garden is to contribute to education. Indeed the conduct of experiments on the larger scale which the garden makes possible often carries a degree of conviction which is lacking from the small-scale work of the laboratory.

The possibilities are so many that only a few may be briefly mentioned here.

Water-culture experiments may be carried out as sand cultures in pots in the open or under glass, and as manurial experiments in the garden. The laying out and preparation of the plots provide opportunity for calculation and measurement; the recording of yields raises some nice problems in the standardization of methods and the use of safeguards; and the final interpretation of the results affords a field for the exploring of scientific method. Manurial experiments may be carried out in conjunction with local agricultural officers, the pupils thus making direct contact with the scientist. Such work has great value, though we must avoid the danger of letting the pupil become involved in an elaborate methodology which he does not understand.

Methods of cultivation and tillage provide an excellent field for experimental work. The effect of surface working, weeding, raking and so on can be explored in terms of changes of water content and temperature in the soil, as well as in relations to crop yield.

The conditions of germination, usually demonstrated in the class-room, can be explored more fully out of doors. The principles and results of intensive cultivation can be shown in the garden and explained in laboratory terms. In fact garden and laboratory must both be used if biological principles are to be demonstrated and understood; for example, simple breeding experiments, carried out in the garden, may be used to illustrate the principles of inheritance studied in the class-room.

Animal husbandry, though not quite so amenable to experiment, offers opportunity for demonstrating on a larger scale what is learnt as theory in the laboratory.

Domestic science, interpreted to include some knowledge of health and hygiene, should obviously be linked with biology and through this with gardening. Lack of appreciation of the importance of nutrition as the basis of health is widespread, and an important aim in education should be to link science and gardening as a step towards better health.

It must, of course, be admitted that attitudes rest upon more than knowledge, and before we can persuade people to apply scientific knowledge to their food habits we have to combat not only economic, but cultural factors. That this is difficult must not prevent the attempt being made, and a first step must undoubtedly be the use of biology to explain the reasons for what is too often thought of in terms of habit. This need should itself help to determine the content of biological education. For example, the study of floral mechanisms, or seed dispersal receives much attention in school biology. It is interesting and important, but less likely to have a functional significance to the individual than, say, a simple study of micro-organisms. Bacteriology receives scant attention, largely because many teachers are themselves unaware of its significance. Micro-organisms play a very great part in everyday life: in agriculture, in health and disease, in food preservation and preparation and in the natural processes of the nitrogen cycle, itself the basis of life.

The economics and biology of home life must be considered a fundamental study, and one which can best be offered through the fusion of domestic science and gardening, through the medium of biology itself. Some of the ways in which this may be attempted can be seen in later sections of this book where specific project studies are described.

Health education has been covered by the remarks already made, though one aspect of it, *sex education*, raises a number of special problems. Among the very few points about which agreement exists in the discussion of sex education there is one of direct importance to the biology teacher. His subject is the only one which, by general agreement, offers a background essential for making sex education effective and normal. Treated in any other way, or in connection with any other subject, sex soon begins to appear abnormal and over-emphasized. The difficulties of the subject are many, the viewpoints diverse, and the lack of any vigorous lead is marked. At the worst a sound biological education must provide a basis for further self-education; at the best it alone can provide the factual and objective data necessary.

Geography, like biology, can play a part in the synthesis of knowledge. Together, the two subjects help each other and contribute to an even fuller view of the unity of knowledge and the interdependence of events. Biology can often be used to demonstrate ideas from geography which may otherwise be developed only by reading and imagination. The response of vegetation to climatic change, for example, cannot be easy for a young pupil to apprehend. He may perhaps be helped by seeing the variations in form of one species in several different environments. In the same way biological knowledge should contribute to understanding geographical ideas about the distribution of plants and animals, about the dependence of man on his environment and, through the concept of evolutionary change, even to the understanding of the cyclic events of physical geography.

Arithmetical methods may be applied to the study of problems in biology, particularly in schools where much attention is given to practical work. The charge is often made that much arithmetical work is divorced from reality, that it sets problems which are meaningless to the pupil because he can see no immediate reason for solving them. While biology is largely qualitative, it offers scope for quantitative work. For example, measurement may be applied in the study of growth, and numerical data may be derived from studies of the water content of soil, population studies and experimental ecology of a simple type. Arithmetical procedures can be used in handling such data. Graphical work and similar forms of presentation may often be adopted. While it must be a central aim to use these opportunities to encourage arithmetical skills, it must not be forgotten that it is at least as important to develop that dependence on critical attitudes known as 'scientific method'. This seldom comes from the mere handling of data; it must be fostered by the teacher. He must discuss it with his class, show how data can be misleading, suggest ways of avoiding errors, and show how the accuracy of our knowledge can be improved by more critical modes of thinking. In school this cannot be done at an advanced level, but may nevertheless be done effectively. The pooling of data, the comparison of individual and class results, the results of using smaller units, larger samples, and so on, may be discussed. The whole aim should be to show that prediction and guessing are not the same, and that where the laws of chance are operative, it may be possible to guess, but never to predict with any hope of success. The discussion should not be left on the purely theoretical plane, it should be illustrated from the experimental data collected by the class and carried over into even more familiar spheres: dog- and horse-racing and football forecasts provide excellent material for discussing and illustrating scientific methodology!

With elementary *science*, represented by *physics* and *chemistry*, biology has obvious relations. These are indeed more easy to explore in the grammar school, but, even where the work has to be simplified, the interdependence of the various scientific fields can be shown.

It is clear that some reference to *geology* is essential, and as much practical work as possible should be undertaken. Without some attention to this subject there can be little hope of appreciating the idea of evolution. Indeed, as an observational science, geology is almost unrivalled, and it is curious that it receives so little attention in a world so greatly dependent upon the materials of the earth's crust.

The teaching of *language* is one of the great tasks of the schools. There is no reason why it should not be more fully appreciated that biology can have a place in this work. Expressional work, oral or written, may concern biological topics, and it may well deal with a personal experience, e.g. in the writing of a description of an experiment or project. In biological fields may be found some great prose which, if carefully chosen, can have all the appeal of adventure and excitement. Biology also has its place in essays and descriptive writings and in the nature-poetry which is so fine an ornament of literature. While these opportunities exist they must not be misused: 'enough is as good as a feast'. The adult can appreciate beauty where the pupil cannot, and a grown-up's interests may carry him through a long travel book of which a child soon tires. Selection must be rigorous and satiation avoided. Quite apart from readings in 'literature', attention should be given to scientific writing in suitable modern periodicals, which are too often ignored in school. (It must be admitted that this link between biology and language is limited chiefly to European languages.)

It is probably unnecessary to give further examples, though there is much material worthy of discussion. *Rats, Lice and History* is the title of a book devoted to a study of biological phenomena in so far as they form a basis of History. The changes in the habits of the herring, resulting from still earlier events, had an effect on the prosperity of the cities of the Hanseatic League. There are many other instances of the social and economic effects of biological factors.

What matters is not so much a knowledge of the interrelation of facts, important as this is, but the development of an attitude, the attitude of the biologist who sees events as the outcome of those which went before and the determinants of those to come. A biological education should affect action in many ways, from boiling handkerchiefs as a germicidal precaution, to spacing the birth of children as a physiological safeguard. This end can only be achieved by those who know biology for what it is, a study of functional interrelationships.

CHAPTER III

METHODS OF APPROACH TO THE TEACHING OF BIOLOGY

If the teaching of biology is to make its maximum contribution to the education and well-being of the child and of society there are certain simple and fundamental rules which must be observed:

(*a*) It must be a practical process in which the pupil, at every stage, is an active participant who deals with things, organisms and situations, instead of being merely a passive recipient of verbal instruction.

(*b*) It should be concerned with living things, their activities and processes, and should not be merely a study of dead specimens, their structure and relationships.

(*c*) It must be a study which is set in wide terms of reference. Biology must start as nature study for young pupils, and must be a continuous experience right up to the specialized work in the upper forms of the school. It must be seen in its relations with other subjects, such as school gardening, home science, health education, physics and chemistry.

(*d*) It must be a study which emphasizes the fundamental unity of the living world, showing that interdependence is a basic biological concept and that man, as an individual or in society, may be studied in biological terms.

Some of the implications of these ideas have already been considered in general terms in the two previous chapters. All of them are dealt with again, in various ways, later in the book. The purpose of this chapter is to consider what teaching procedures can be adopted in order to ensure that these four rules are put into practice.

Biological education must start very early in school life in the form of nature study, and must have a strong practical bias. Even children who live in a highly technical world have strong interests in living things. It appears probable that this same interest exists among all children, though, in some lands, social pressure and religious belief may make this less obvious. The least we can say is that this important interest in living things should be stimulated and developed. We must make sure that this is done as a basis for later work, and we shall never do it unless we start early and study life itself.

In some countries, the teaching of biology, even at the earliest stages, has been too much a matter of instruction, detail and abstraction. Formality, a complex terminology, and a demand for memorizing can make what has a natural appeal to the child seem dull and difficult. We should replace these practices, and the attitudes which go with them, by materials and methods which stimulate an active interest during all stages of education.

Work with young children (*aged 6 and 7 years or even less*)

At this level the work must be absolutely informal. It may include some or all of the following:

(*a*) *Hearing and telling stories about animals*. These should be chosen to illustrate how animals live, rather than to point some moral. Literature and folk-lore are often rich in opportunity, though some care in selection is necessary. The field is so wide that the only possible suggestion is that teachers should choose suitable stories from the folk-tales of their own country, many of which may never have been written down, existing only in traditional verbal form and handed on from one generation to another. Those who have the ability should not hesitate to make up stories, but, whatever is done, there must be a clear line between fact and fiction.

It should also be noted that animal stories have often been translated from the original into various other languages. Here too, care in selection is essential, because the setting may be unfamiliar to young children.

(*b*) *Singing, dancing and dramatizing stories about animals*. These activities often provide a sense of sympathy and reality. For this reason they should be used freely, but again the line between fact and fiction must be clear, and children should be encouraged to be critical of what they are told, what they see and what they do.

(*c*) *Making simple models of animals.* Clay may be dug from a river bank, or ant-hills, or bought from a potter or brick-maker. Although modelling in clay is a caste occupation in some places, most rural parents are not concerned if their young children do it. (In the town any antipathy of this kind is usually far less marked, though this rural–urban difference is greater in some territories than others.) Models may also be made in other materials, or carved in soft wood when the children are old enough. In the early stages it is best to use the traditional methods of the locality.

(*d*) *Collecting flowers or growing them from seed.* The collecting of flowers or flower petals for church decoration or temple offering is accepted by all, and there seems to be no objection to the idea of using flowers for other purposes. In some densely populated towns, even in the poorest quarters, people often seek some touch of beauty by growing plants, especially creepers with bright flowers: the ground is thus prepared for such an activity in school. Those who know the drab schools of certain towns and villages are likely to agree that flower gardening gives an air of gaiety as well as engendering new attitudes.

(*e*) *Watching and learning about animal ways.* The habits of the gecko and other common animals are often known only because they are supposed to have a magical or other meaning, especially in regard to future events, but they can be used for nature study also. Where do geckos live? What do they feed on? There are plenty of questions to be solved. There are also other animals to be observed: the humble snail, the chipmunk or squirrel, even the rooks and crows busily engaged in practical public health work by scavenging. All can be studied, not only in order to learn about their particular habits, but to learn something of how to think in scientific terms from the earliest possible age.

(*f*) *Keeping pets.* Lack of space and the impossibility of locking up most schoolrooms make the keeping of pets difficult, but something may be done. ('Pets' may not be the best word to use.) An aquarium offers endless interest and may be set up with little more than a few jam-jars or a battery jar. With very simple cages, life histories of insects may be studied, for example the stick insect, the mantis, the lace-wing, the silk moth. Children find interest even in such commonplace creatures when given the chance. Such work must be carefully organized to ensure adequate provision of food and water for the animals. This may also help to encourage sympathy and kindness towards animals and to develop a revulsion towards cruelty.

In work of this kind the emphasis must be on seeking knowledge through experience. It should be 'fun' to do such things, and children should be encouraged and helped to do as much as possible for themselves. If there must be attention to 'gains in information', let the knowledge be sought from nature and only in the last resort from books. Success, at this stage, is to be judged by the quickening of interests and the forming of attitudes, not by memory and the ability to repeat. At the same time we must not dismiss the formal side, and we ought to have some kind of general guide as to what is possible with young children. This is a question of curriculum, which is dealt with in Chapter IV.

Work with juniors (up to 11 or 12 years)

As children become older, and their skills and attainment increase, the work expected of them should become gradually more complex. Among junior children, biological work should have a strongly practical basis, which may be of the kinds already mentioned. The emphasis must be on activity, upon exploration and experimentation.

The most frequent fault with biology, as taught in many schools, is that its content is too formal and its methods unpractical. Children should be developing attitudes and interests, but instead they are far more often struggling to learn details, especially of structure, and are overloaded with words beyond their comprehension. This kind of teaching is partly the result of the verbal approach to learning, a heritage of tradition, and partly of a mistaken belief that the earlier the start, the greater the chance of success in dealing with complications of structure and nomenclature. Tradition is hard to break, but common-sense alone should make it clear that to ignore the child's interests, and to burden him with what he cannot understand, results in boredom and frustration.

Those who teach junior children should set before themselves two simple but important aims:

(*a*) To work in terms of problems in biology which are within the understanding of children, and which are likely to stimulate interest.

(*b*) To seek results in the attitudes and activities of children, and to be concerned with children's interests rather than in what they can remember.

Only those who have an extensive first-hand acquaintance with teaching and schools can appreciate how great a degree of re-orientation of attitudes is required among teachers before these two aims are accepted. But, until they are accepted, biology will continue to fail to make the important contribution to social progress of which it is capable.

The work should thus be a continuation, at a slightly higher level, of that begun in the earlier years.

Work with secondary school children

In the secondary schools children are older and likely to have been 'streamed' in some way. Many, in schools of the more academic kind, are already setting out on a programme of studies which reflects very strongly the influence of the syllabus and the examination system. Others, considered to be less able to do academic work, are in some other kind of secondary school, from which they leave at an earlier age to seek employment. The effects of this cannot be ignored. They operate in many ways, especially in terms of school amenities. (Africa and Asia tend to differ from the other continents merely in emphasizing more strongly the prestige of academic as opposed to 'practical' education.) The higher status of the academic schools usually carries privileges, particularly a higher proportion of trained and graduate staff and better facilities and materials for teaching.

Despite this difference, real or apparent, it is difficult to believe that the needs of the two groups of children, in relation to biological education, are in any way qualitatively different. If there is any difference it is likely to suggest that the underprivileged require a 'better' biological education than the others, because they are more likely to live in the less favourable environments, where the effects of poverty, ill-health and insanitary conditions are most marked. All that can be done here is to discuss methods of approach, in general terms, and leave it to the teachers to ensure that they use them as best they can for their children's needs.

There are in particular two points which require special emphasis:

1. Biological education must be practical.
2. Biological education must be social.

These points are complementary to each other and must guide the teacher in framing a syllabus as well as in putting it into action. It is therefore very important to consider the following suggestions:

(*a*) Provision should be made in the time-table for practical work, which should be of double-period duration. The amount of time involved must relate to the biology programme as a whole, and should be from one-third to one-half of this. The arrangement of demonstrations, in connection with 'theory' periods, should not be forgotten, because the distinction between theory and practice is one of convenience rather than reality.

(*b*) The plan of the practical work must be related to the seasonal availability of material and should be worked out in detail before the start of the course. Every pupil should have a copy of this plan and should always know how his individual progress relates to this plan and its timing.

(*c*) Lack of laboratory amenities or equipment should not be taken as an excuse to limit practical work. The teacher—and very often the class can help him—should collect materials, save up anything which may prove to be of later value, and engage in an extensive attack on difficulties by means of improvisation.

(*d*) The school natural history society should be used in functional relation to biology teaching. Its members, for example, may well help in the making of apparatus and models.

(*e*) A school garden is an essential, and the question of how to use it is discussed in Chapters II, VI and VII. It is mentioned here as an important factor in the general approach to teaching.

(*f*) Informal out-of-school activities which relate to biology should be encouraged, and the teacher must be prepared to react with sympathetic understanding to children's interests—which may range from keeping stick-insects to watching elephants. Whether or not it is in the syllabus is immaterial, for use should be made of every opportunity to widen interests in biology.

(*g*) Biological teaching should be related to other subjects, and in particular to the affairs of mankind. Radio, newspapers, magazines and films frequently contain material which is either directly biological or closely allied to biology. Attention to them, and discussion of them, must be welcomed.

(*h*) The teacher must make it his task to anticipate, and meet with sympathy, that special group of problems resulting from particular forms of fundamental and religious belief. It is difficult to suggest how this is to be done, but some way must be found. In most cases it may come down simply to a consideration of the claims of the many against the one. And often it may involve the teacher in the acceptance of responsibilities which his pupils refuse, for example, in the taking of animal life.

With these provisions in mind, we may now turn to consider how the teacher can approach his class—or rather in how many ways, because we must avoid the common mistake of sticking to one method, especially when tradition has made it verbal and passive.

Class teaching, in the traditional sense, cannot be given up: it has many virtues, providing the pupil is an active participant. The teacher must seek ways to ensure this. For example, instead of talk by the teacher, reading by the class, and the final test by questioning, he may introduce a subject briefly, point out the main problems, and then let the pupils seek the answers for themselves. This they can do in several ways, such as by reading in textbooks, using reference books in the library, discussion among themselves, or practical work in the laboratory or field. The method adopted must relate to the conditions of the moment: the great thing is to make the class active, both physically and mentally.

This approach to teaching, if it is to be successful, involves a good deal of preparatory work by the teacher. He must divide up the syllabus into convenient sections; he must consider how much he should contribute to each and what he expects the class to do; he must know that adequate resources exist and are available for the class to use. All this must be worked out beforehand. Good teaching demands good planning.

Nor must the teacher do all the teaching. It is symptomatic of poor methods when a teacher describes himself as 'lecturer in biology'. Unfortunately the description is often true, for many lecture and few teach. The wise teacher explores every avenue which permits his pupils to be active, verbally and in other ways. One device, quite often used, is the 'lecturette' by a pupil. It can be successful, but often fails because it lacks basic reality, the pupil merely condensing part of a textbook. It is much more likely to succeed when the pupil reports something he has *done*. Much of this may be verbal activity, but it is more personal when a pupil tells of his visit to the library, of how he sought help, of finding that the books disagreed, of going to the museum or the zoo, or of doing some field-work in an attempt to solve the problem for himself. The pupil talking about such activities is dealing with reality; he is concerned with understanding and not with mere remembering.

Work of this kind need not be individual, but may be a group activity. A major topic may be taken over by two or three friends, who divide it up, do their work, write a joint account, and nominate one of the group to present the report. Their report should not be purely verbal: they may bring specimens, notes, diagrams, collections of material, posters, and so on.

One form of group activity which is often used is the debate. Many teachers think highly of the method, though it may often become artificial because pupils are dealing with material of which they have no first-hand experience. A debate seldom achieves anything which cannot be done by a well-directed class discussion.

The project method

It is natural to follow up these suggestions by reference to what is probably the highest development of pupil activity, the 'project'. This method is much neglected in many schools, particularly at the secondary academic level. The project offers an 'activity method' admirably suited to biological work. Projects aim at solving problems which have definite meaning to pupils, and make use, in a real setting, of methods natural to them. The theme of a project study must be a large one, such as 'How does our town get its food supplies?' or 'What is evolution?', and must be related to interest and experience. Themes of this kind are large enough to occupy a group of workers, and the work can be divided up among them according to their interests and abilities. It is this social aspect of project work which is so important: it provides opportunity, offers variety (so that individuals can take over those parts to which they are best suited), challenges activity, and brings teacher and pupil into a new kind of democratic relationship.

In many countries project work has received very little attention. It may be helpful to deal with a few of the important questions asked by teachers when the method is first described to them.

How is a project study started? The teacher must have a problem in mind and be able to raise interest among his pupils without saying 'Here is a job for you to do'. Once the class realizes there is a problem, the next step is to seek suggestions as to how to tackle it. The teacher must not dictate what is to be done, but must encourage initiative. He must let pupils plan what to do and then decide who is to do it. If obvious errors are made, he must decide whether he should step in at once, or let his class learn by experience. He can suggest books to read or consult, places to visit, people to ask, and so on. He must tactfully help in ensuring that the proposed plan is possible, and he must help class discussions, in which every pupil is given opportunity to contribute knowledge and ideas, ask questions, and make suggestions. In this preliminary stage the teacher must play a leading part, because he has knowledge and experience not yet possible to children. At the same time he must not allow this to lead him to impose his ideas too strongly, but should remember that one of the most important values of project work comes from this preliminary discussion. The children learn how to organize work for themselves and to accept responsibility in a co-operative activity.

It is always helpful to have a guide to the discussion so that the informal preliminary work goes forward in a suitable manner. It is found in most cases that the stages of development are:

(*a*) Deciding exactly upon the problem to be studied. A vague or too extensive concept may result in a diffuse study which seems to lack purpose or result.

(*b*) Deciding how the major problem can be conveniently broken up into subsections without losing sight of the main theme.

(*c*) Deciding which groups of children are to be responsible for the parts of the study and how they may carry out their work.

(*d*) Deciding how the various parts are ultimately to be related to each other, and how this relationship may be kept in the foreground throughout and made clear at the conclusion of the work.

Of course it is usually the teacher alone who is able to see the plan as a whole at the beginning. Moreover, he must be constantly ready, throughout the whole course of the work, to help and encourage pupils. He should do this not so much by giving direct answers to their questions as by guiding their discussions and suggesting new lines of thought and new sources of information. It is in this way that he can help his pupils to greater understanding and more logical ways of thought.

Examples of projects:

(*1*) *A study of fossils*

Background. Although this is a very simple project it possesses certain points of interest. It arose spontaneously from a child's problem and was carried out to completion with a minimum of school facilities. A new boarding-school had been started, but the class-rooms were not quite ready. A teacher found himself in a village, near a small town, with a group of boys, aged between eleven and thirteen, with whom he was unfamiliar. Some sort of educational activity had to be arranged. On the day after arrival it was decided to walk through the village and on to a nearby hill, in fact to undertake a very informal survey.

How the problem arose. All the children came from big towns. Very few had been into the country and all found their new experience very exciting. After leaving the village, which had been fully explored, the group sat down on the hillside near a small quarry. Within a few minutes a number of boys had gone to look at the quarry and had come back with a few fossil shells, which are very common and easy to collect in that area. They all asked the same question: 'Please, sir, what's this?' And, of course, others were equally ready with answers: 'It's a snail', 'It's a stone', 'It's a shell', and so on.

Here was a problem posed by children themselves. Here too was an admirable chance to try to teach something about scientific method, as well as about general biology, instead of merely giving a direct answer.

Defining the problem. Having got the eager and excited group to sit down and talk in turns, instead of all together, the teacher began to guide discussion along certain lines in order to give the question greater meaning. 'What's this?' could have been answered in a few words: 'Oh, that; well, it looks like a fossil shell, probably one called *Rhynchonella globosa.*' To someone who fully understood the implications of the question, that answer would have meant, for instance: it was a fossil form of a brachiopod living in the remote Jurassic age; that the place where it was found had once been under the sea; that earth movements or a recession of sea-level had taken place; that at the time when the animal lived there had been certain conditions of climate, flora, fauna, water salinity, etc.; that certain chemicals had been present and certain chemical changes had taken place, resulting in preservation of the original shell as a fossil; that forms of life have undergone changes, since identica shells are no longer found.

These are only a few of the 'meanings' which would come to the mind of one with some knowledge of biology, geology, and evolution. Some knowledge of such things may be looked upon as desirable as part of a general scientific education. The search for this knowledge offered a way of both providing training in scientific procedures (however simple) and knowledge itself.

The first job then was to expand the question, to give it greater meaning. So, instead of giving an answer, more questions were asked. The conversation went something like this:

'Jones, why did you say, "It's a stone"?'—'Well, sir, it's the same colour as the stones round here, and it's heavy, too.'

'Smith, you said, "It's a shell,". Why?'—'Please, sir, it looks like a shell, it's got ridges on it.' 'Now, Brown, do you think it's a shell?'—'No, sir.' 'Why don't you think it's a shell?'—'Well, shells are not made of stone, and anyway you find them in the sea, or on the beach.'

Everybody began to talk at once, and the word 'fossil' was being used by several boys.

'White, what is a fossil?'—'Sir, you find them in museums.' This is where young Gray said, 'Don't be a fool! You mean you can go and see fossils in our museum at home. But they didn't find them there. They dug them up, out of a quarry somewhere, like this one.'

At this point it was clear that some boys had heard of fossils, knew that there were fossil shells, and that they were found in quarries and such places. So the conversation was turned in another direction.

'Brown, you said that shells were found in the sea and on the beach. Now, if this is a fossil shell, what other question ought we to decide?'—'How it got here, sir, and how it changed into a fossil from a shell.'

'That's right. Well now, what is the difficulty about it being found here?'—'This is not the sea, and we are not anywhere near the sea. Besides, we are up on a hill. And I've never gone uphill to the sea-side, sir.'

There is no need to recall the conversation any further in detail. The main thing is to realize that these boys had now turned a simple question into a complex one. Even though they had not answered the first question they had found out that it meant more than they thought it did at first.

Making a plan of work. It became clear that there were several jobs to do, several questions to answer. As a result the following list was made:

1. To find out whether any other fossils could be found, either higher up or lower down on the hillside.
2. To find out whether the sea had ever covered the hillside on which all this took place.
3. To find out something about shells.
4. To find out more about fossils and how they are formed.

Arranging for the work to be done. The first task obviously involved some further exploration, and this was planned for a later day. It was decided that the other jobs would need other methods, such as asking people, reading books, looking at maps and going to a museum. The details of all this remained to be settled.

Next day it became clear, as so often happens in project work, that the boys had become really interested. Meeting in an empty shed, because there was no room in the school, they were ready with information, ideas, books, maps and even some more fossils. This was because their interest had led them to make an effort on their own the night before. Each of the boys had gone back to the village full of questions. Thus the villagers too had become interested. (This is an example of one valuable aspect of project work: interest spreads over from school to home, from child to grown-up; in fact it becomes an important kind of voluntary adult education.)

First of all a number of new ideas had to be dealt with, because it is always wise to think before acting. So the whole morning passed, each boy having his say and the group discussing it. Of course this led to still more questions, such as:

What made the levels of sea and land change?

How do we know that some rocks are older than others?

Why do fossils occur in some rocks and not in others?
Is the animal still inside the fossil shell?
Why do we not find shells of this kind (that is, the one from the quarry) at the present time?
Are there any fossil snails like the snails in our gardens?

It is important to notice how a list of questions grew from the direct discussion of the first one. This is what we so often miss in normal class-room teaching: the increased understanding to be gained from verbal exploration of a question and its implications. It is desirable to foster this kind of discussion because it gives training in two important mental skills:

(*a*) recognition and greater understanding of factual data

(*b*) ability to distinguish between facts which are known and other ideas or postulates which may be factual, but have not yet been shown to be so.

The boys were divided up into small groups. It was suggested that close friends should work together, that boys should choose a group in accordance with their interests and abilities, and that older boys, or those most used to going about by themselves, should form any group which might have to visit the local town.

The code letters of the groups, the task undertaken by each and the methods it was proposed to employ are shown in Table I.

Carrying out the work. A. This group marked all the nearby hills on a map, located all the quarries and paid a visit to each. From each quarry they collected fossils and also made notes and some sketches.

B. This divided into three sub-groups. The first collected snails and other shells from gardens, ponds, roads and paths in the district. The second sub-group spent one day in the museum and then did some field-work. The third spent two days in the library. Sub-groups 2 and 3 made many notes, traced maps and collected a few relevant pictures.

C. This group met the parish priest, who not only knew his geology, but increased the interest of the boys. Eventually they spent three days with him doing field-work, collecting, and making maps, because, as he said, 'You cannot start to learn

TABLE I

Group code letter	Task problem	Methods proposed
A	To find out whether fossils could be obtained locally at higher or lower levels than the quarry	Exploration of the vicinity by walking, aided by map. Fossils to be collected and locations marked on map
B	To find out more about shells	Collection of living snails. Visits to local museum, reading and reference library
C	To find out more about fossils, their formation and significance	Visits to local museum and reading library. Interview parish priest (who was said to be interested). Visit a school (3 miles away) where children had made a museum of their own
D	To investigate land movements	Interview geography master. Talk to quarry foreman

geology from books or schools. You must work at the job in the field.'

D. Group D interviewed the geography master. They reported, very politely and with a show of reluctance, that he was not much good. In fact, he was an excellent geographer, but a poor teacher. He almost killed their interest by telling them what they wanted to know in a way they could not understand. They went off rather resentfully to see the quarry foreman, but came back full of excitement. They had some idea of faults, strata and sequence, even though they had learned far more about drilling charge holes and firing explosive shots than about land movements.

Results. A combined meeting was held and one boy in each subgroup and main group reported what had been done, how it had been done and the chief results.

Next, all the specimens, maps, etc., were laid out and examined, questions being asked and criticisms made by the boys.

A final discussion took place, and then the following conclusions were drawn:

(*a*) Fossils are records of past life, formed by the chemical changing of the bones and shells of animals.

(*b*) Some rocks have been formed from sand and mud which have become hardened by pressure and chemical change.

(*c*) These rocks have been laid down layer after layer, and the relative order is a sign of relative age.

(*d*) Some rock layers have various kinds of fossils. Some kinds of fossils may be found in several rock layers.

(*e*) There has been considerable movement of the rocks in relation to the sea, but how these were caused is uncertain.

It was realized that this was by no means a complete story, but the boys had learned, for themselves, quite a lot about geology and its relation to zoology. In addition, their interests had been aroused and they had learned something about scientific method.

The work did not end there. One or two boys became interested in coal and oil from a geological point of view. Three boys set out to make a set of maps of the area. Another made a clay model in relief. Several spent much time collecting fossils. Two saved up their pocket money and bought books (and one of the books proved much too difficult for its purchaser, who thereby learned the value of getting advice before buying a book). Several boys followed a different line. Having seen some flint arrow-heads in the museum they developed an interest in prehistoric man. And of course one or two boys were disgruntled and lazy throughout the whole proceeding.

This is a simple description of a very simple project, but it demonstrates an important truth, that most pupils learn better when they are teaching themselves under the driving force of their own interests. Interest begets effort and effort is the first step towards success.

(2) *A study of water*

The study of water in relation to human needs gives admirable opportunity for a project or activity study. First of all it is within everyone's comprehension, because we all need water for washing and drinking. Secondly it is a matter of common experience, because the life round the well, the state of the village tank, the flow of spring or river, and the anxieties of flood and drought, are matters of everyday interest. Thirdly, it is a very important study, because water-borne infection is one of the greatest of health problems. Fourthly, it is within the bounds of possibility. Here is a real, understandable, common and important problem about which something can be done. It has many aspects, it calls for many kinds of activity, and it provides co-operative work for those with widely different interests and abilities.

As an example of such a study we take a description of a study made by a class of thirty-three boys of about fourteen years of age. As set out in Table II the scheme shows how the

TABLE II

How we get our water: Topic 1. Water sources

Work to do	Method	Group
Make a list of local water supplies	Use your own local knowledge	A (five boys), were all interested in scouting, camping, walking
Classify as: well, spring, river, etc.	Ask questions	One was very good at drawing
Draw a large map of the location	Go for walks	
Study local geology and find how it affects water supply	Look at maps	
Draw a map showing local geology	Visit local museum	
Draw a section of local rocks	Visit library; ask for books likely to be useful, especially for local reports	
Make a profile of local river		
Find out why villages are in certain places		
Make a sand-table map		
Make a relief map with clay		

Topic 2. Water supply

Work to do	Method	Group
Draw large map, on big scale, to show local reservoirs, water-works, mains, wells, etc.	Enlarge from 1″ map; or trace from 6″ map	B (four boys) Father of one boy was employed at the water-works
Draw profile section through reservoirs to town to show gravity feed	Work from a contoured map	These boys were interested in engineering and building. One was a good draughtsman
Make scale of local heights	Look for local bench (survey) marks	
Make diagram of processes at the water-works	Write for permission to visit water-works	
Find out storage capacity and average consumption	Ask questions Make notes	
Estimate how much water is used by each person each day in the town	Ask to borrow Annual Report. (Remember to *return* the Report)	
Find out about seasonal variations in consumption	Write letter of thanks	
Make diagrams to show seasonal variations of rainfall		
Make a map of the watershed area which supplies the reservoirs		

Topic 3. The water-works

Work to do	Method	Group
Make larger scale drawing of the water-works. Label the parts. Show their functions. Make separate process diagram to show the order of the purification processes	As for topic 2	C (four boys), all interested in model-making
Make models of filters, etc.		
Make models of the works as a whole		

Topic 4. The physical properties of water

Work to do	Method	Group
Determine the freezing point of water	Refer to books	D (five boys), all interested in science
Determine the boiling point of water	Work in laboratory if possible	
Find out about temperature scales	Make experiments with simple makeshift apparatus	
Make experiments on the expansion of water when frozen and heated	Find out how this knowledge is applied in various ways	
Experiments on convection		

Topic 5. The chemical properties of water

Work to do	Method	Group
Water as a solvent: find out whether salt and sugar are more soluble in cold or hot water	Read books Do experiments	E (three boys), all very keen indeed about chemistry
Evaporate salt solution and reclaim the salt	Visit office and laboratory of the public analyst	
Is there anything dissolved in ordinary river or pond water? Find out by evaporating	Ask for information	
Might this be dangerous?	Ask local nurse and doctor	

Topic 6. Biology and the water supply

Work to do	Method	Group
Collect pond water and find out what kind of organisms are living in it	Collect in jam-jars Use hand lens and microscope	F (six boys), all interested in natural history
Note greenish-blue scum on edges of drains	Make some drawings Look up biology books	
Examine tap water for living organisms	Read	
What water-borne diseases are important?	Talk to local nurse and local medical officer	
How are they caused?	Look up annual reports of medical officer of health	
How are they transmitted?		
Make charts and diagrams to show incidence of these diseases during the past years	Visit Public Health Department Look at reports	
Think out precautions needed to keep water pure, consider positions of wells, etc.		

Topic 7. Government and the water supply

Work to do	Method	Group
Find out about the history of water supplies	Use the library	G (three boys), all interested in history and civics
When was the local waterworks first built?	Read history books Ask the history teacher	
Find out which departments of the Local Authority are concerned with water supplies	Visit the secretary of the Local Authority Visit the local engineer and the water-works office	
Do people pay for the water they use?		
How much is spent locally on water supply?	Visit the accounts department of the Local Authority	

Topic 8. Water in the home

Work to do	Method	Group
Make a diagram of the cold water supply (if any) in your home	Make a simple model to show the effect of 'head' of water	H (three boys), all keen on model-making
Note the mains which supply taps (faucets)	Make model for house water systems	
Why are they buried below ground?		
Find out how the inlet supply is automatically controlled		
What scientific principles are involved?		
Find out how a tap (faucet) works	Take a tap to pieces and learn to fit a new washer	

work was divided into sections, what had to be done in each section, what methods were to be used and how many boys worked at each part.

The whole project lasted throughout a single term of thirteen weeks and the work occupied one whole afternoon, from 2.0 to 4.0 p.m., each week. Much more time was given to it because, as interest grew, boys stayed to work after school hours, and they also gave time to it in their out-of-school activities, when they made some of the visits mentioned. Often their teacher went with them on Saturday afternoons, but they also organized such expeditions themselves.

This project was carried out in a limestone district, with reservoirs supplying a town. For that and for other reasons it could not be copied exactly elsewhere. Slavish copying is not desirable, however, and this should be taken as a scheme to illustrate what has been done, and which should be modified to meet local conditions.

Those unfamiliar with project work will say: 'How can we afford a whole term on one topic?' They should note that this topic has many sides. It calls for work in geography, history, science, hygiene and health education. It gives opportunity for many skills: map-making, using a library, making notes and writing reports, drawing and painting. It is a problem with real meaning for children; it strikes at their interests, challenges them to activity, and brings them into contact not only with facts and theories but with people. It is a training in the arts of living, in responsibility, in co-operation, in the ways of democracy.

A brief summary of practical procedures in organizing work of this kind may be useful:

(*a*) The full plan should first be discussed with the whole class so that everybody knows what it is.

(*b*) In arranging the various sub-groups of boys who are to work together, members of the class should be allowed to choose their own partners whenever possible.

(*c*) A rough time-table, showing dates by which certain stages of the plan are to be completed, should be drawn up.

(*d*) Each group should know what it has to do and how much time and money it is allowed.

(*e*) Discussion meetings should be arranged every third or fourth week, so that each group may report on its work, questions may be asked and answered, and the parts may be seen to make a whole.

(*f*) The teacher must keep in close touch with all that is going on, because he is the real link between the various parts of the scheme.

(*g*) A final meeting, at which each group can make its contribution, should be arranged.

(*h*) Every effort should be made to hold an *exhibition* for parents and public. All those who helped in any way should be invited. Each group of boys should take charge of its own section and answer questions.

(*i*) Lastly, and this is very important, failures as well as successes must be prepared for. Success lies not in neat maps or writing, but in changed attitudes in the minds of children and their parents.

For the purpose of a project study, wherever it takes place, the principles should remain the same, however greatly the details have to be modified. For example, it is usually only the larger towns which have a mains water supply. In some rural areas the major topics to be dealt with might be as follows:

(*a*) Discussion—our need of water. What happens if we get no water? Experience. Experiments on the wilting of plants.
(*b*) Where do we get water? Rain, wells, springs, rivers.
(*c*) Is water pure? Discussion of impurity and infection.
(*d*) How does rain-water become impure? Solvent action. Infection and contamination—how it happens. How to avoid it.
(*e*) Purifying water. Boiling. Filtering. Experiments with filters.
(*f*) The siting and making of a well. Keeping the well clean.
(*g*) Water and the mosquito. Fighting malaria—drainage, oil films, DDT, etc.
(*h*) The simple geology of water supply. Porous and impervious rock layers. The location of springs and wells.
(*i*) Water shortage. The village and town tank, or other supply.
(*j*) Mains water supplies. Reservoirs. Gravity feed. Watershed area.
(*k*) What the water-works does—collecting, storing, filtering, purifying and distributing water.
(*l*) Saving water—why and how.

Such topics may be arranged in a smaller number of suitable groups and a project carried out as previously described. The emphasis should be on practical work by the pupils, with plenty of discussion at all stages.

We must not think that 'such work may be all right in Europe or North America but will not do here'. The background is different in various places, and some teachers have more experience than others, but teachers and pupils in every country are just as capable of such work. Their major problem, the reaction of parents who do not think that projects are school work, has also been met almost everywhere. Such an attitude was defeated in Europe and North America by experience, children developing a passion for school work of the new kind and making amazing progress, and teachers beginning to think of their job as a vocation instead of merely a way of earning a living.

(3) *A study of factors involved in plant survival*

The study of plant ecology and plant dispersal is a constant theme in most biological syllabuses. Whatever is done to make the topic practical, and to present it as a problem, it is often true that, for most pupils, it remains merely as a set of facts to be learned and remembered.

However, in a secondary school of academic type, a teacher was able to show that the subject may be explored by methods which provide some real experimentation.

The particular school had extensive grounds in which there were several soil types (a light loam, a heavy clay area and one field of a sandy nature). Gardening was a popular school activity which, as the interest spread, meant that new gardens were frequently brought into being by clearing and digging new pieces of ground.

While talking to a small group of boys the question of weeds arose. One boy said, 'Well, I've got nothing but grass in my new plot.' Others said, 'Oh, well, I've got weeds,' or 'I've got a lot of little trees of some sort.' A thoughtful boy remarked that it was curious to find such marked differences, all within close reach of each other, in the grounds of one school. Finally he said, 'I suppose it's a matter of chance; it just depends what gets there first.' To this another replied, 'But is it not also a question of what succeeds—you know, survival of the fittest, and all that?'

The teacher said, 'I expect you have each got whatever grows next door to your little plot.' The thoughtful boy gave his usual slow smile and said, 'Maybe, but we still have the problem though—why is *that* where it is? Why has Smith got trees? And Jones got grass? and so on.' Of course he was right. This was not a little question, about little plots, but a big question, about big principles.

The obvious thing, soon decided upon, was to do something about it, not try to talk it out, but to work it out. The following brief record is presented to show how, under 'project conditions', faced with a problem which has meaning to them, pupils can plan a sound piece of work. In this context the planning is perhaps more important than the work itself, so that no reference is made to the latter. First the planning is recorded and then the suggestions and comments, taking each point in turn.

Action suggested	*Comment*
1. 'Dig over a new plot and see what comes up.'	'Yes, but we cannot tell from that whether the new crop comes from seeds already in the ground.' 'And even if the seeds are not in the ground already, they may get in after the digging.'
2. 'Well, dig the plot and then cover it with a box in one place. Under the box you will get what was in the ground already. Outside it you will get what comes into the plot from outside.'	'No! Outside the box we shall get what was in the ground, and also what comes from outside.' 'But surely nothing will grow in the dark under a box? Besides, it will keep the rain off, so the ground will be too dry.'
3. 'Well, instead of a wooden box, use a glass frame for a cover.'	'That would let light in, but still keep rain out.'
4. 'All right, then you will have to lift it off and water the ground every night.'	'We still have to separate what is there already from what comes in later.' 'Surely that is just an argument by differences. I mean we only have to compare the two areas with each other. The differences between them are due to the presence of the box.'

This account need not be continued further. It is enough to show how pupils may be allowed, helped and encouraged to think about their problems. This is the essence of scientific method, and the problem is more easily tackled by the project method than by the traditional methods of learning from a textbook or from set experiments.

In this particular study the boys eventually divided up into a number of groups, each of which took a specific point to investigate. No one of the results, taken by itself, would have provided a complete study of the factors, nor even of one factor involved in plant survival. Taken as a whole, however, the results did give, so far as could be expected from school work, a comprehensive story. Here again is a point of value in the project method: it emphasizes the function of co-operation in the search for knowledge.

Finally the method, in this instance, led to another important point—the need for verification. These boys produced a theory which many would have accepted at once. Fortunately one was sceptical and said it ought to be tested, a suggestion which led to a much wider study of the germination of tree seeds.

CHAPTER IV

THE BIOLOGY SYLLABUS AND ITS TREATMENT

Developing a course in school biology

It is perhaps unfortunate that the syllabus is often laid down by an examining body or a central authority. One result of this is that local needs and conditions tend to be overlooked; another is that urban requirements frequently receive more attention than rural needs. Moreover, these conditions, tending towards the neglect of the less advanced areas in any country, are most often found in the least advanced countries. It is there that differentiation and regard for local conditions is most useful. But it is also there that local awareness and responsibilities are least developed, so that central control seems necessary to secure progress and set standards.

In view of such situations teachers may well say that the problems of curriculum construction are not theirs. All that they have to do is to 'cover' the syllabus given to them. Yet in order to do this a knowledge of curriculum construction is desirable. More important is the fact that teachers may be required to assume increasing responsibilities, and one of these must surely relate to the syllabus and curriculum. It should also be noted that not only do teachers, through their associations, contribute to progress in education, but it is from their ranks that the inspectors and administrators come. By ensuring that teachers understand all aspects of the curriculum problem, it is also made possible for future educational officials to be functional, as well as titular, leaders.

A curriculum, irrespective of its subject-matter, should be based upon certain guiding principles which provide a rationale. For a very long time it was customary to consider one, or at most two, such principles. On the one hand every effort was made to cover the subject and preserve its logical nature and content. On the other some attention was given to the general differences of ability of children of different ages. Such principles are not to be neglected today, but it is also customary now to take into account other features, especially in the social sphere. Among the more important points to which attention should be given are:

(*a*) The content (and method) should, at every stage, be related to pupils' abilities, interests and experiences.

Inherent in these are the effects of increasing age and differences of sex, and related to them are the following criteria of which mention has already been made:

(*b*) It should contribute to a training in science method as well as to the gaining of knowledge about biological phenomena.

(*c*) It should aim at the understanding of principles, as well as the mastery of details.

(*d*) It should contribute to the formation of attitudes and the acquisition of habits in addition to gains of understanding.

(*e*) It should help the individual to a clearer understanding of his or her own functions and responsibilities in life.

(*f*) It should contribute to an understanding of social life and responsibilities.

These conditions may be satisfied by several methods of approach. For example, many teachers claim that biology, as presented in the most widely used school-books, which are largely structural and systematic, realizes these outcomes. Critics point out, however, that this common (even classical) approach may give an understanding of some aspects of biology, but that it probably fails to illuminate the social issues which are so important. There are other possibilities. The whole concept of biology, and still more of its applications, may be altered by choosing different themes around which to build the curriculum. Among such themes two may be taken as examples.

I *The study of major biological principles*

In this case the whole course is orientated towards a comprehensive view of the great principles of biology (see Chapter II). The difficulty is that principles emerge from details, so the pupil must be in command of a considerable body of detailed knowledge before he can start. Thus this approach is best used towards the end of school life, when it can act as a comprehensive over-view of all that has been done, putting the various small parts into their proper perspective.

Suitable categories for arranging the major principles have been given in Chapter II, though of course others are possible. The next step is to expand these in order to show the teacher the materials he needs, and to some extent the method he should adopt in teaching. As an example, here is a note on the treatment of biogenesis:

Biogenesis: Description, definition, importance, applications.
Development of the idea—history of science—reading matter.
Demonstration by paired experiment and control: mould on bread, souring of milk, etc.
Further experimentation: plate cultures, water moulds, etc.
Significance: food preservation, hospital techniques, visits to see use of aseptic methods in food preparation, hospital, etc.

This note is enough to suggest that a pupil cannot get a real understanding of biogenesis merely by reading a book. It is a complex topic requiring much thought. The pupil needs various kinds of experience in order to build up a conceptual principle and to follow its application. The work must therefore be made practical. If the pupil is to rely on more than mere memory, all his needs must be considered, and the teacher must plan how to meet them in detail. This brief outline of biogenesis gives a broad indication of what is required, but it omits the details necessary in particular for the less experienced teacher. As a guide to a more detailed analysis a further major principle may be discussed.

The principle of evolution

Evolution, the major unifying principle in biology, presents many problems, particularly to the pupil. It rests upon a mass f detailed evidence of many kinds, but the pupil has only a mited knowledge. It demands an appreciation of time-scales, knowledge of past life forms, some understanding of geological equence, and a realization of the cumulative effects of minute hanges continued throughout geological time. Further the ignificance of variation should be appreciated, and this is difficult because, for various reasons, the pupil sees few examples of ny particular species. The pupil has to think about the subject, or the formulation of a concept is a process dependent upon hought and not only on memorization. Thus there are few opics where it is more necessary for the teacher to think out nd organize his plans than the teaching of evolution. One cheme which may be used as a basis is suggested here.*

undamental questions in evolution

. Is the living world entirely different from the non-living vorld, or can both be studied, described and explained under a common set of principles?

. Is the vast variety of organisms evidence that they are in ll ways separate entities, or is there some kind of relationship which brings them into a fundamental unity?

Principles which are fundamental to evolution

(*a*) Biogenesis. Unless organisms arise only from other organisms, and not *de novo* by spontaneous generation, there is no basis for a relationship in time and space.

(*b*) Unity of type. Unless organisms give rise only to others of the same type, relationship is replaced by chaos.

(*c*) Succession in time. Unless organisms have followed each other in time and complexity there can be no sequential relationship whereby the complex have evolved from the simple.

(*d*) Variation on a genetic basis. Unless there is a mechanism of genetic inheritance, variations which appear in the individual cannot be preserved in the race.

An analysis of this kind helps some teachers to see that they have never previously thought out the basis of the argument for themselves. They have described the theory of evolution and then gone on at once to the evidence for it, thus failing to offer any real understanding of the problem. It is only after crystallizing these basic principles that attention should be given to the question of evidence. This evidence is usually presented under the following headings:

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* This analysis of the basic questions and principles which must underlie a theory of evolution was originally made by Professor L. Hogben.

(1) *Palaeontology*. The fossil record is in many ways the most 'telling' piece of evidence for evolution, and certainly it is one which makes an appeal to pupils. There are two things which every teacher should do.

(*a*) Select two or three groups (for example, the elephant or the horse) and prepare material to illustrate their evolutionary history. This may consist of illustrations from books and articles, picture-cards from a museum, diagrams and charts to show the time-sequence, etc. Such material should not only be demonstrated by the teacher, but examined, handled, thought about and used for practical work by pupils. Models may also be made by the pupils.

(*b*) Seek ways of helping pupils to become familiar with fossil material. Excursions in the locality may provide some, or a visit to a museum may be made. Where neither can be arranged, it may be possible to arrange an exchange with another school in a suitable area, giving local biological specimens in exchange for fossils from elsewhere.

(2) *Comparative anatomy*. Exhibits should be prepared to show the homologies of the vertebrate limb in various types, the development of the brain and the like. Again use is made of pictorial and diagrammatic materials, but actual specimens should also be used. Pupils learn much from helping to prepare these specimens.

(3) *Embryology*. Many pupils fail to understand even the broad principles of embryological development, and so can never use it as evidence of evolution. The fault usually lies in lack of practical acquaintance with suitable specimens, models and pictorial materials. Here also the teacher should prepare illustrative materials of as many kinds as possible, such as models, diagrams, slides and photographs.

(4) *Systematics*. Pupils tend to miss the contribution which systematics can make to the study of evolution because their knowledge is so often confined to type specimens. To gain wider knowledge, field-work, excursions, collecting, etc., should be encouraged through a school natural history society.

(5) *Distribution*. Except in relation to local ecology the pupil sees nothing of the problem and significance of distribution. The only way to help is to prepare distribution maps of as many kinds as possible, with a particular emphasis on evolution.

(6) *Biochemistry*. It is too difficult to provide suitable material for school use, except perhaps a diagram concerned with blood groups.

Some teachers may consider that treatment of the kind suggested above is concerned more with the approach to teaching, with the method, rather than the content of the syllabus and curriculum. There may be some truth in this, but it is also evidence of another point: that the division between content and method is rather artificial. The convenience of the division is a danger: in deciding *what* shall be taught the question of *how* it shall be taught gets overlooked. In laying down plans for a curriculum and syllabus all teachers, especially those with comparatively little experience, should keep both points in mind.

The two examples above, showing how the syllabus may be centred on the study of major principles in biology, draw attention to three facts:

(*a*) The principles are so extensive that they may easily seem vague and lacking in clarity, and in any case they are inevitably so large as to require lengthy periods of study. Hence it is essential to plan the work in some detail.

(*b*) Pupils find such large topics, referring to diverse fields of knowledge, difficult to follow and work upon, unless given considerable help by the teacher.

(*c*) The method demands much thought on the part of the teacher. This is valuable. Instead of 'going through' a syllabus, he has to decide how to select and arrange a variety of material in order to illustrate his theme.

II *The 'project' or 'centre of interest' approach*

The project method in relation to biology has been described in Chapter III, where the principles of the method and examples of its use are described. In order to give further help to those who wish to use this method a few suitable topics may be mentioned here.

1. *Growth.* What do we mean by growth? Is growth confined to the living world?
How does growth take place?
What factors affect it?
How can it be measured and recorded?
Can it be controlled experimentally?
Are there optimum conditions for growth?
What do we know about human growth?

2. *Population.* How do we obtain information about the population?
How has our population changed in the past?
Is it changing now?
What changes are likely in the future?
What other characteristics are important in addition to total number? (Sex ratio, age-group composition, etc.)
What factors affect population changes?
What is the relationship between population and food supply?

3. *Genetics.* What is meant by inheritance?
What kinds of qualities are inherited?
Examples of inheritance.
The work of Mendel, Bateson, Punnet, Morgan, etc.
Simple experimental work.
The mechanism of inheritance; genes and chromosomes.

Other similar topics for which the teacher may work out a brief scheme of procedure are:

1. Milk and its importance.
2. Adaptation to environmental conditions.
3. Vitamins and their significance.

III *The physiological approach*

A course of biological studies based on physiology helps pupils towards an understanding of organisms in terms of life processes. More important, perhaps, it lays a foundation on which an understanding of society, in biological terms, becomes possible. Moreover, this approach makes clearer the interdependence of biology and other subjects such as physics and chemistry, thus emphasizing the unity of scientific knowledge.

Such an approach does not mean that morphological and anatomical studies have no value. It extends their significance by relating form to function. The divisions, like that between content and method in education, are artificial; convenient but sometimes misleading. The teacher should try, as far as possible, to treat the two aspects (form and function) together. Form and structure may often be demonstrated more easily than function, but use may perhaps be made of models, especially of simple diagnostic functional models.

A main outline for a syllabus based on physiology (that is, on the functional rather than the structural aspects) may be arranged, for example, by considering each main function:

Respiration.	Its relation to metabolism and energy exchange. A demonstration of respiration. The respiratory organs. The hygienic aspects of respiration. The differences of respiration in animals and plants.
Digestion.	The need for energy; food as a fuel. Oxidation of food substances. The mechanics of feeding, ingestion and digestion; enzymes. Food values. Plant and animal feeding.
Excretion.	Nitrogenous waste in animals; where it is formed. Excretion and the kidneys. Elimination of waste.

Movement.	Animal locomotion.
	Locomotory organs; mechanics of movement.
	Exercise and rest.
	Plant movement.
Response.	The nervous system of animals.
	Evolution of the central nervous system.
	Sense organs.
	Simple behaviour and learning.
	Plant responses—tropisms.
Reproduction.	Its significance.
	Asexual and sexual reproduction.
	The sex cells.
	Differences between animals and plants.
	Its evolutionary importance.
	Its relation to communal and social life.

IV *The sociological approach*

In view of the social significance of biology in education it is essential to consider whether social biology may be used as the main theme of a course of school biology. Here is the 'contents' list of a pioneer work in this field.*

1. Life in space and time.
2. Man and evolution.
3. Man as an animal.
4. Maintaining the human species: sex.
5. Maintaining the human species: inheritance.
6. Maintaining the human species: reproduction.
7. Man and his health: social hygiene.
8. Man and his health: history of medicine.
9. Food and drink.
10. The balance of nature.
11. Social life among animals.
12. Some reasons for Man's success.
13. The nature of life.

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* *An Introduction to Social Biology* Alan Dale, by permission of Messrs Heinemann Ltd, London).

Another approach to this same problem is shown in the following Table of a course in social biology which was organized at a particular school:

TABLE III

First year (age-group 8–10).* *The general activities of organisms*

1. The differences between living organisms and inanimate objects.
2. The differences between plants and animals.
3. The general activities of organisms.
4. Why plants need food. What they use, how they get it, how they use it.
5. Why animals need food. What they use, how they get it, how they use it.
6. How new plants are formed.
7. How new animals are formed.
8. The dependence of young animals on their parents.
9. Different examples of parental care.
10. Elementary ideas on sex differences.

Second year (age-group 9–11). *Your body and how it works*

1. The shape and parts of the body.
2. Structure and function of the skeleton.
3. The brain and what it does.
4. The sense organs and their work.
5. Muscles and movement.
6. The gut and its functions.
7. Kidneys and excretion.
8. The heart and blood system.
9. The lungs and respiration.
10. The reproductive system.

Third year (age-group 10–12). *The biology of health*

1. Why the body needs energy.

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* When children start such a course at a later age they must nevertheless cover the early work. However, as they are older they are able to cover the work more quickly.

2. Food as the source of energy and the basis of growth and health.
3. What growth is. How is it measured?
4. Factors affecting growth. Food. Vitamins, etc.
5. Work, exercise, fatigue, sleep and rest.
6. Sunlight and its importance to living things.
7. What causes illness and disease?
8. Health, a positive biological ideal.
9. The origin and growth of a new individual.
10. Final development and birth of a new individual.

Fourth year (age-group 11–13)

(1) *The physical evolution of Man*
   (*a*) What we mean by the term 'evolution'.
   (*b*) How scientists developed the idea of evolution.
   (*c*) Some stages in the physical evolution of Man.

(2) *The development of mind*
   (*a*) Elementary ideas about animal behaviour.
   (*b*) The brain of Man compared with the brain of other animals.
   (*c*) The importance of tools, speech and writing.

(3) *The idea of specialization*
   (*a*) The simplest organisms composed of a simple cell.
   (*b*) Specialization, differentiation, beginning of complexity.
   (*c*) Specialization of cells for reproduction.
   (*d*) The sex cells and fertilization in different animals.

Fifth year (age-group 12–14)

(1) *The evolution of society*
   (*a*) Families and tribes.
   (*b*) Nomadism and the rise of agriculture.
   (*c*) The beginnings of customs and laws.
   (*d*) The beginning of the State.

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(2) *The idea of the State*
  (*a*) Some early ideas about the State.
  (*b*) Wars and their causes.
  (*c*) Communication and exchange.
  (*d*) The mutual interdependence of States.

(3) *The basis of family life*
  (*a*) Sex and the formation of new individuals.
  (*b*) Human reproduction, family life and parental care.

Remove forms (age-group 12–15)

(1) *The rise of religion*
  (*a*) What do we mean by religion?
  (*b*) Origin of religion, fear, awe, wonder and hope.
  (*c*) Some primitive religious ideas.
  (*d*) Some ideas about the great religions of the world.

(2) *Religion and society*
  (*a*) Religious belief and social structure.
  (*b*) Is there an antithesis between religion and science?
  (*c*) Must religious belief and action be modified as society changes?
  (*d*) How far can we plan for the future?

(3) *Human reproduction*
  (*a*) The formation, development and protection of the foetus.
  (*b*) Animal and human families. Breeding seasons. Size of families. Maturity at birth. Growth rates.

Sixth year (age-group 13–16)

1. The principles of inheritance.
2. The population problem.
3. Health, disease and society.
4. Family problems.
5. Habits and instincts.
6. What determines character?
7. The study of personality.
8. Mental health.

9. Individual and social morality and responsibility.
10. Further sources of knowledge.

Sixth Form (pre-university work)—based on:

- (1) Extension of the sixth-year syllabus.
- (2) Reading of one or two suitable texts such as:
    - (*a*) McDowell: *Biology and Mankind*
    - (*b*) Howard: *The Proper Study of Mankind*
    - (*c*) Walker: *On being a father*
    - (*d*) Dale: *An Introduction to Social Biology*
- (3) Consideration of special topics such as:
    - (*a*) Causation and controlling of population changes.
    - (*b*) Biological, social and economic factors related to age of marriage.
    - (*c*) When should children be born: early in marriage, close together, at a particular season?
    - (*d*) Contraception.
    - (*e*) Parent–parent and parent–child relations.
    - (*f*) Organization of family life.
    - (*g*) Hygiene of pre-school child.
    - (*h*) Mental and social needs of pre-school child.
    - (*i*) Some important educational problems.

Some other syllabuses

Examination bodies and education authorities are usually responsible for syllabuses. They include the material considered suitable for pupils in the particular age-group. Ideas of suitability vary a great deal. Moreover, it is often necessary to adapt any syllabus according to local conditions.

In this chapter an attempt is made to show how syllabuses may be approached in various ways. But the outline of work presented by a syllabus can never indicate the importance of the teacher's attitude. However, several bodies have tried to develop a syllabus suggesting a less rigid treatment than has sometimes been required in the past. Three examples of this type, bringing out the broad general principles of biology, are now given here.

Biology in a General Science Course.[*] The items in this list were chosen because they are connected with pupils' everyday contacts and with fundamental principles. Teaching material is readily available almost everywhere.

The chief aims are to show:

1. The reactions between living organisms and their environment.
2. Adaptation produced in the course of evolution as the result of these reactions.
3. The relationship of vital activities to physical and chemical concepts of energy.
4. The foundation for some simple laws of hygiene.

Living matter. Distinction from non-living matter; cells, growth. Animal and vegetable kingdoms. The animal as a heat engine; the plant as a reversed heat engine. (Link with relation between heat and work.)

Food and fuel. The importance of plants in building up food and fuel. Formation of coal. Assimilation; storage of starch, sugar, etc. Cereals and other crops. Respiration. (Link with composition of air.) Transpiration. (Link with underground water.)

Simple agriculture. Formation of soil. Manures; fixation of nitrogen. (Link with nitric oxide.)

Plants: adaptation and associations. (Link with soil.)

Pollination and fertilization. Seed and fruit; distribution.

Natural selection. Variation: Mendel.

The simplest plants. Any motile green alga (scum from pond or rain-water). Moulds, e.g. mucor, yeast. Bacteria. Practical applications; Pasteur; infection; sterilization; Lister.

Animal tissues. Protoplasm as physical basis of Life; cells and cell growth, e.g. epidermis; tissues, e.g. muscle; organs.

Protozoa. Some common Protozoa, e.g. Amoeba or Paramoecium; marine Protozoa. Effects on earth's surface of

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[*] The list given here is abstracted from the General Science Syllabus prepared by a sub-committee for the Science Masters' Association (of Great Britain). The syllabus is intended for pupils intending to take General Science as an examination subject at the School Certificate level, that is, for children in the 11–16 age-group.

Foraminifera and Radiolaria. Parasitic Protozoa; malaria, and life history of mosquito.
Balance in Nature. Earthworm as agricultural agent. Bees, ants, wasps, aphides. Habits and life histories of fish, birds and mammals important to man. Reproduction.
Evolution. Darwin.
Human physiology. Brief survey of respiration, blood circulation, nutrition, nervous action, and sense organs in Man.
Elementary Hygiene. (Link to accidental constituents of air.)

Practical Biology. Section 1

(1) Grow crystals. Compare growth of seeds.
(2) Collect oxygen from plant leaves assimilating in water in sunlight.
(3) Collect carbon dioxide from respiring pupil.
(4) Simple tests for (*a*) starch, (*b*) sugar.
(5) Assimilation experiments with living plant:
  (*a*) Starch in green leaves in daylight.
  (*b*) No starch in banded leaf, variegated leaf, starved leaf (plant kept in dark).
  (*c*) Soda-lime, bell-jar; live plant forms no starch, control plant forms starch.
(6) Obtain ammonia gas from some organic nitrogen source, e.g. hair or manure.
(7) Grow plants in: (*a*) complete culture solution; (*b*) culture solution with no nitrogen compound.
(8) Respiration: (*a*) Carbon dioxide from growing plant in dark. (*b*) Germinating seeds, e.g. in closed funnel with soda-lime, funnel dipping into mercury. (*c*) Germinate seeds in Petri dish with methylene blue solution.
(9) Transpiration. Darwin's potometer. (Live shoot; thistle funnel, with stopcock, through cork into jar full of water.)
(10) Examine simple plant; root and shoot.
(11) Examine and dissect a simple flower.
(12) Examine pollen, ovule and other microscopic preparations.
(13) Examine a few typical dry and succulent fruits, etc.

(14) Specimen Mendelian maize-cobs; demonstrate any Mendelian experiments.

Section 2

(1) Grow seedlings (e.g. maize, peas, beans) in wet sawdust.
(2) Examine standing rain-water for one-celled, motile green plants.
(3) Grow white mould (Mucor) on damp bread or manure.
(4) Grow green mould (Penicillium) on orange, etc.
(5) Grow yeast and examine; prove evolution of carbon dioxide and 'fermentation'.
(6) Make an infusion of dried grass; filter and leave standing to 'ferment' (cloudy—clear—scum [zoogloea] on top).
(7) Bacteria in air and in saliva. Destruction of bacteria by ozone.
(8) Examine water in which flower stalks or dead tree leaves have steeped for some days, for various one-celled free-swimming animals (paramecium, etc.).
(9) Examine Foraminifera and Radiolaria slides; chalk and flint.
(10) Breed mosquitoes, caterpillars, stick-insects, etc.
(11) Observation hive or Formicarium.
(12) Examine ready-made dissection of frogs (freshly made, if possible; otherwise, permanent preserved specimens).
(13) Examine blood corpuscles, muscle-fibres and bone slides.
(14) Skeletons of bird and mammal for comparison.
(15) Examine and open a bullock's eye (obtainable from butcher).

*General Biology Course.** This syllabus has a definitely social basis.

Part I

(1) *Glimpses of the drama of life in nature.* The life of animals and plants in nature. Growing and multiplying; ageing and dying.

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* A syllabus based on that produced by the British Social Hygiene Council in 1932. (For pupils in the 11-16 age-group.)

(*a*) Note of endeavour: the seeking for food and suitable environment, and for mates. The battle with the elements.

(*b*) Note of healthfulness: there should be an exhibition of healthy living organisms, such as a squirrel, a bird, tree-frogs, small vivarium turtles and newts; also a Lubbock Formicarium (ants), and a Nicholson observatory hive (bees).

(*c*) Note of youth: some study of young animals, such as lambs, kids, calves, foals, and downwards to tadpoles and caterpillars. Different forms of 'animal play', e.g. sham-race, sham-hunt, 'King of the Castle', and a mere hint of the biological meaning of play.

(*d*) Note of joyousness and affection: the song of birds, the gay colours of flowers. The affectionate mate-partnerships of parrots, badgers, rhinoceroses. The care of parents for offspring.

(2) *The everyday lives of familiar animals and plants.* For these studies such familiar organisms as the housefly, earwig, earthworm, frog, pigeon, rabbit, cat, dog, a tree, a shrubby evergreen, a flowering plant may be used. The same living things should be studied at different times of the year, in order that the broad details of their life history may be seen.

These questions should be asked:

(*a*) What is this? Here the broad external features should be studied.

(*b*) How does it work? This should be determined as far as possible without dissection, in the early stages of the work. The answers to this question introduce the functions of feeding, breathing, excretion, feeling, movement, reproduction.

(*c*) Where does it come from? This should bring out the broad details of the life history, showing development.

(*d*) Why is it like this? Each part of the organism has its uses. The answers to this question should show how well adapted most living things are to their natural surroundings, e.g. a fish to life in water, a frog to an amphibious existence.

(3) *Study of structure and function.*

(*a*) Plants:

The parts of a typical plant: root, stem, leaf; flowers as modified leaves; seeds. (Pupils examine a growing and readily flowering 'annual' at intervals throughout the year.)

(*i*) Study of large buds. (Pupils should make a series of drawings showing transition from bud-scales to leaves.)

(*ii*) Study of 'bulbs' and 'corms'.

(*iii*) Study of flowers. The parts of a typical flower, and their functions. (Mere dissection of flowers is subsidiary, yet provides a fascinating exercise, develops manipulative skill and acts as a discipline in precision. It may be made educative in other ways, e.g. when pupils discover real relationships between plants that are superficially very different.)

(*iv*) Study of fruits and seeds. (Inquire into the structure of simple common fruits of different kinds. After these are mastered, pass to difficult fruits, such as pomegranate, fig, etc. Study interesting and puzzling fruits, such as orange, coco-nut, ground-nut. Take a particular case such as wheat or oats, separate seeds from fruit-case, make flour, dissolve out the gluten, inquire into the meaning of 'chaff', 'bran', etc. Sow some seeds. Study the structure of large seeds, such as those of bean, pea, orange, and discover the meaning of the different parts.)

(*b*) Animals:

The external and internal parts of some familiar animals. Head, body, limbs. Brain, sense organs, nerves; heart, blood-vessels; food-canal; excretory and reproductory organs; muscles.

The functions of these parts.

(A great deal can be done by suitable demonstrations of dissections prepared by the teacher. In some countries museums have excellent series of animal dissections. Detailed study should be avoided. Concentrate on the broad features. The earthworm and the frog are particularly fascinating for dissection with young pupils.)

(4) *The relation of living creatures to their surroundings.*

(*a*) Plants:

Plant associations, i.e. societies of plants usually found together in similar habitats, and often, though not related to one another, showing the same kind of fitness for particular conditions of life. Thus, there are the plants of grasslands, roadsides, farmlands, road and rail cuttings, forest, rocky hills, mountains, the shore, swamps, ponds, riverbanks, lakes, etc. (Select a particular habitat and study the competition for room, light and air. How many plants have much cut-up leaves; why? How many different ways of climbing up are there? Scramblers, twiners, leaf-climbers, tendril-bearers. Give examples.) Relation between plants and the seasons. The seasonal states of trees and evergreens. Annual and perennial plants. The difficulties overcome by plants that exist through cold or very dry seasons.

(*b*) Animals:

Animals and their surroundings. (Study the animals to be found in different regions, e.g., a pond, a river bed, the seashore, rocky and sandy areas, farmlands, the forest, etc.) The relation between animals and the seasons. Migration of birds. Seasonal coats.

Comparison of particular haunts at different seasons. (Contrast, for instance, conditions of a pond, a shore pool, a stretch of the beach, a particular piece of land at different times of the year.)

(5) *The interrelations of animals and plants.* Herbivorous animals, arboreal animals; animals that are parasites in or on plants; plants as parasites on plants and on animals; plants as partners; pollination of plants by insects; scattering of seeds by insects.

The relations between animal and animal; predatory relations; parasitic relations, mutualist relations. Nutritive chains, e.g.

gull, fish, crustacean, worm, diatom. 'All flesh is grass'. Competitive relations in Nature, direct and indirect. (Inquire into the rotting of withered leaves and of dead animals, the work of moulds and other fungi, the action of bacteria. Try to show by a simple experiment that there is no rotting without bacteria. Try to make vivid the general idea of the circulation of matter, which is continually passing from one form to another, from one incarnation to another, indestructibly. Much that seems to vanish into the air in the form of gas may be recaptured and brought into the circle of life again. This work must be carefully graduated according to the pupils' knowledge of chemistry and physics.)

Animals and plants in relation to Man. (An interesting series of studies may be arranged. Part of the work may be held over for the season when the supply of objects for study is difficult. In towns where opportunities for nature study are necessarily restricted, considerable emphasis should be laid on utilitarian aspects.)

(6) *The physiology of living creatures.* (If, because of shortage of apparatus, the pupils cannot do the experiments themselves, demonstrations should be arranged by the teacher. Much of what can be done in physiology depends on the pupils' knowledge of chemistry and physics.)

(*a*) Plants:

Photosynthesis in green leaves, the most important life-activity in the world. Simple experiments on starch formation. Colouring matter in leaves and flowers. Some simple experiments, e.g. with solutions of the green colouring matter, separating the pigments, with 'anthocyanin' in acid and alkaline solution. The water-current from roots, through shoot to leaves. Experiments on the ascent of sap. The breathing of plants; usually masked by the photosynthesis, but noticeable at night. Digestion in plants. Starch turned into sugar, etc.

(*b*) Animals:

(Experiments with animals are very difficult to undertake in elementary work, but from a consideration of structure much can often be deduced as to function. Demonstrations of dissections are particularly valuable in this part of the work. Many simple experiments can, however, be carried out by the pupils on themselves, e.g. the increased beating of the heart during exercise.)

Respiration. Simple experiments on breathing; comparison between breathing and burning.

Circulation. The heart and blood-vessels. How they work. Blood and its uses. Simple experiments on the 'beating' of the heart.

Demonstration of a sheep's heart.

Nutrition. How food becomes blood. Different diets; herbivorous, carnivorous and omnivorous animals. Dissection of the food-canal of a rabbit.

Excretion. The getting rid of waste and poisonous matter. The kidneys, the skin. Defaecation.

Sense perception. The sense organs, the nerves, the brain.

How the sense organs work. Demonstration of dissected bullock's eye.

Movement. Muscular action and its control by the nervous system.

Reproduction. The function of the reproductory organs. Gestation.

Development. It is easy to show a frog's egg developing into a tadpole. It is not difficult to show an embryo bird within the egg-shell. If possible, a mammalian embryo should be studied.

(7) *The behaviour of plants and animals.* Tropisms in plants, e.g. the sensitive mimosa; growth of plants towards light; growth of roots downwards; the day and night movements of flowers; the twining of tendrils, etc.

Involuntary animal movements, e.g. 'beating' of heart; reflexes. Instinctive behaviour; intelligent behaviour. Voluntary movements. The formation of habits.

(8) *Plants and animals under the microscope.* If microscope work is impossible or restricted, teachers should make full use of lantern slides, film-strips, etc., to cover the matter contained in this section. The work must be made interesting and understandable to the pupil. (The importance of an understanding of the matter in this section cannot be overrated.)

A drop of ditch-or pond-water under the microscope. Small plants and animals. The life-cycles of some simple types; Amoeba, yeast, chlamydomonas, paramoecium. The general idea of the cell, illustrated by unicellular organisms. The multicellular organisms: an organized community of 'life-units', i.e. cells. The simple structure of tissues: their cellular character. Ova and spermatozoa of animals, ovules and pollen grains of plants. The essential fact of fertilization in the life of organisms.

(9) *A simple classification of living creatures.* (Only a very simple classification should be attempted. The aim should be to show the broad differences between the big groups of organisms. Classification should not be attempted until the pupils have had some considerable teaching of different types of living creatures. It should crystallize the pupils' experience, and should be particularly valuable as a basis to the lessons on evolution.)

The two Kingdoms:

(*a*) The Animal Kingdom. The simplest animals; Sponges; Stinging animals; Lower worms; Ringed worms; Echinoderms; Arthropods (e.g. Crustaceans, Insects and Spiders); Molluscs; Primitive Vertebrates; Fishes; Amphibians; Reptiles; Birds; Mammals.

(*b*) The Plant Kingdom. The simplest plants, e.g. Diatoms, Desmids, Bacteria; the Algae; the Fungi; Lichens (dual plants, Alga and Fungus in partnership); Liverworts; Mosses; Ferns; Horse-tails, Clubmosses; Conifers; Monocots; Dicots.

Part II

(1) *The place of Man in Nature.* (*a*) Physiological. Man as a higher animal. The essential similarity between animal and

human functions. Human anatomy, physiology and hygiene. Health and disease. Reproduction and development of Man compared and contrasted with that of animals.

(*b*) Psychological. Human behaviour compared and contrasted with animal behaviour. The ascendency of intellect in Man. The significance and value of habits.

(2) *The general principles of evolution.* (The teaching should be very elementary and should be based on the pupil's own experience of types of animals and plants. This may be supplemented by special examples, e.g. the evolution of the horse. Evolution can best be approached by a consideration of types from below upwards in both animals and plants.)
Evolution as seen in the three lines of evidence:

(*a*) Geological. The story of fossils and what they show. Coal, chalk, etc.

(*b*) Embryological. The development of embryos. Recapitulation. How the human embryo possesses, at successive stages, gill slits, a tail, etc., relics of long-ago ancestors.

(*c*) Morphological. The evidence of the vestigial remains; in Man, the appendix, Eustachian tube, etc. Resemblances and differences between groups of animals.

The mechanism of evolution. Some idea of the struggle for existence and consequent selection.

Variation and heredity. Illustrations from domestic animals and cultivated plants to bring out some of the simple facts, e.g. dogs, pigeons, rabbits, etc.; roses, etc.

(3) *Associations among animals and human beings.* Gregarious animals, e.g. sheep. Truly social animals: ants and bees, rooks and beavers. Man as a social being.
Sex in animals. The relations between male and female animals. Courtship and mating in animals, e.g. cats, pigeons, nightingales. The differences between male and female; the male usually the active member, the female the passive member. Consider this in plants, animals, Man. These sex differences are psychological as well as physiological.

Sex in the human being. Adolescence and growth of sex impulse. The control of these impulses. Love and its potentialities in human beings. Courtship.

The animal family. Development of parental care. Different ways in which animals care for their young, e.g. nests, burrows, pouches. Nourishment of the young. Defence and training of the young. Different kinds of animal family; maternal, paternal and bi-parental. The human family. The family as the social unit. Life-long associations between men and women. Marriage; monogamy. Human parental care and responsibility.

(4) *Man and Nature.* The immense gulf in intellectual capacity between Man and the most intelligent animals.

The increasing measure of control Man is gaining over his environment. His growing control of animals and plants, as well as of the inanimate forces of Nature. Evolution is going on: we must think of it operating in the present. Man's responsibilities as an intelligent being.

An Introductory Course. As a third example, here is a scheme* for an introductory course in biology for the lower forms of a grammar school or for pupils of less academic secondary schools.

How animals and plants live

(1) *Life histories of selected plants and animals.* The selection depends to some extent on the facilities afforded by the school neighbourhood. Outdoor studies should, however, always be supplemented by the care of some living plants and creatures in the class-room.

Senior-school pupils should not rest content with merely observing the growth of living things, nor even with admiring the process. Their interest should, under guidance, lead them to seek for rational explanations, and to begin to make and test hypotheses. The work is thus a definite extension and not a mere repetition of the nature study in the junior school.

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* Designed by a committee of teachers in London.

(*a*) Pond life: the keeping of aquaria for the purpose of studying the life histories and habits of water-plants, water-beetles, dragon-flies, caddis-flies, frogs, small fish, etc.

(*b*) Insect life: the keeping of vivaria for the purpose of studying the life histories of moths and butterflies. The life histories of the bee, humble-bee and wasp are also appropriate for study.

(*c*) Bird studies: pupils should learn to identify the common birds and gradually acquire some knowledge, where possible, of their song, and their habits in and out of the nesting season.

(*d*) Seeds and their germination (e.g. peas, maize): experiments should be set up to determine conditions necessary for germination. Diagrams of growth should be drawn and the discovery made that light is necessary for healthy growth.

(*e*) Plants should be grown from bulbs and corms.

(2) *Breathing*. (*a*) General. Experiments to show that some oxygen is absorbed and some carbon dioxide given out during breathing in human beings.

Comparison with combustion of candle.

(*b*) Plants: Experiments to determine whether
  (*i*) Oxygen is necessary for plant life;
  (*ii*) Carbon dioxide is a waste product.

Examination of leaf skin: stomata and their function.

(*c*) Animals and human beings.
  (*i*) Elementary study of the heart.
  (*ii*) Nature of the blood.
  (*iii*) Distribution of the blood-arteries, veins and capillaries.
  (*iv*) General circulation of the blood; work of William Harvey; blood pressure and the pulse; valves of veins.
  (*v*) Change of arterial to venous blood and vice versa.
  (*vi*) Changes in the air breathed.
  (*vii*) Simple structure of respiratory organs; trachea and lungs.

(*viii*) Pulmonary circulation and relation to general circulation.

(*ix*) Movements of chest-wall in breathing; the diaphragm; importance of absence of constriction by clothing.

(*x*) Ventilation; importance of fresh air.

(3) *Feeding.* (*a*) Green plants. Experiments to show

(*i*) Presence of starch in green leaves.

(*ii*) Presence of water, mineral salts and carbon in green leaves.

(*iii*) That starch is composed of water and carbon.

(*iv*) That the plant needs
Light;
Water;
Certain mineral salts;
Carbon dioxide.

(*v*) How the plant obtains water and mineral salts.
Experiments on transpiration; simple root structure; experiments on osmosis and root pressure.
Soil in relation to plant life; composition of soil shown by experiment. Rotation of crops. Manures, natural and artificial.
How soil is formed.
Animal life in the soil; garden pests.

(*vi*) How plants obtain their carbon. Experiments to show
That presence of chlorophyll is essential for starch formation.
That presence of carbon dioxide is essential for starch formation.
That presence of light is essential for starch formation.
That in sunlight plants absorb carbon dioxide and give out oxygen.

(*vii*) Storage of starch in parts of plant which are not green. Conversion of starch into sugar.

(*b*) Plants without chlorophyll; parasites, e.g. fungi.

(*c*) Animals. Brief summary of foods of mammals; proteins, carbohydrates, fats, salts, vitamins and water.

The alimentary canal, e.g. of the rabbit, illustrated by charts.

Elementary study of functions of salivary glands, liver, gall-bladder, pancreas and spleen.

(*d*) Human beings. Diagram of human alimentary canal. Relative percentage of foodstuffs in certain foods.

Mixed diet; object of digestion.

Teeth; importance of mastication.

Lining of alimentary canal.

Elementary study of glands and secretion.

Action of saliva. Digestion in and structure of (*i*) the stomach; (*ii*) the intestines.

Pancreatic juice. Liver and spleen.

Assimilation and protein formation.

Ferments and fermentation; yeast and bread-making; bacteria, hormones and vitamins.

Hygiene of food and its preparation.

(4) *Excretion of animals.* Removal of waste products from living tissues by the blood through

(*a*) Lungs: carbon dioxide and water. Dealt with in connection with pulmonary circulation.

(*b*) Kidneys: urea.

(*c*) Skin: water.

The kidneys: position and simple structure. The skin: simple structure; perspiration. Hygiene of the body. Importance of regular habits.

The study of the breathing and feeding of plants and animals introduces pupils to some very important ideas:

(*a*) The dependence of living things upon their inanimate environment, sun and air, earth and water.

(*b*) The interdependence of all living things.

Studies of plant and animal communities, to illustrate the balance between plants, animals and their environment, may be made an important part of the work. It may be carried out in any accessible habitat. Ponds, river-banks, grassland, forest, farmland, swamp, the seashore, may be made the subject of observation. Aquaria, vivaria and the school garden also afford opportunities for similar studies.

(5) *Growth and reproduction.* The increase in size of living matter through division of cells, and the cell as the unit of living structure, are matters of interest and importance. Suitable objects for microscopic study in this connection are amoeba, blood corpuscles, yeast, etc.

Reproduction of flowering plants:

(*a*) Study of pollen, i.e. male cells. Forms of pollen grains; experiments on germination of pollen.
(*b*) Study of pistil with ovary and ovules, i.e. female cells. Structure of ovule.
(*c*) Pollination: self and cross.
(*d*) Fertilization; growth of pollen tube.
(*e*) Seeds and development of fruits.
(*f*) Seed dispersal.

The life histories of the frog and of birds have been suggested above as appropriate for study. The development of the frog from spawn and of the chick from the hen's egg may be taken up more fully as illustrations of animal reproduction.

(It is probable that class instruction in this topic should not include mammals at this stage. The pupils, however, are familiar with the notion that the other essential processes of life, breathing and feeding, with their resultant growth and excretion, are common to almost all living things. They are trained to think about such processes in a relatively impersonal way, even when the processes are considered in relation to human beings. Thus, pursuance of the topics suggested in this section gives some preparation for facing the problems of sex; and the knowledge gained should at least act as a steadying influence when such problems become important in the individual lives of young pupils.)

Organization of the time-table

In developing a course in school biology it is essential to take into account the time factor, which operates in two ways.

(*a*) The various parts of the syllabus must be studied at a time appropriate to the logical development of the subject and the availability of materials. Development has been considered already by showing how the materials of the course should be arranged in groups and topics concerned with important biological principles. The question of availability must be determined locally. In temperate, and still more so in extreme conditions, seasonal variations dictate when certain parts of the syllabus can be studied. Seasonal variations are less marked in the tropics, but it is equally necessary to plan the order of work to fit in with them.

(*b*) There is a time factor in relation to the rate of learning and working. Learning is a complex activity involving the rearrangement of knowledge, the perception of new relations and the creation of new concepts. Such processes take time. Pupils do not 'see things in a flash'; they need time for ideas to mature, and the more complex the idea, the longer the time needed. It is clear that the relative time for mechanical procedures must be considered carefully: to dissect a large and complex vertebrate requires more time than to dissect a small and simple animal.

Young teachers with limited experience, and still more those who are just beginning to teach biology, find difficulty in knowing how to arrange the school periods available to them. Details depend upon some factors which are specific to given conditions, but general suggestions, capable of modification, may be given here.

Allocation of periods. In the lower classes biology is usually taught as part of General Science. In the last two years before pupils take an examination such as 'School Certificate', the subject may be taken separately. The suggested distribution of periods is shown in Table IV.

When pupils enter 'the sixth form', that is, when they begin pre-university work, specializing in science, the number of periods required is greatly increased. Although the approach to biology should remain the same, much more detail must be

TABLE IV

A minimum number of periods for biology with pupils (age-group 13–16) in the two years before a 'School Certificate' examination

It is assumed that:

(*a*) 'Periods' are of 40 minutes each.
(*b*) There are at least 33 full weeks in the school year.
(*c*) The complete course takes 2 years.

Periods (each 40 min.)	Per week		Per year (33 weeks)	
In class, single	1	3	33	99
In class, double (one)	2		66	
Private study, 'preparation' or 'home-work'	3		99	
Total	6		198	

Note. A few exceptionally able pupils may cover the work in one year. A few of the less able may require three years.

TABLE V

The number of periods in biology suitable for pupils (age-group 16–19) preparing for examinations such as 'Higher School Certificate', 'Advanced level', open University scholarships, etc.

It is assumed that:

(*a*) 'Periods' are of 40 minutes each.
(*b*) There are at least 33 full weeks in the school year.
(*c*) The complete course takes at least 2 years.

Periods (each 40 min.)	Per week		Per year (33 weeks)	
In class, single	2	12	66	396
In class, double (four)	8		264	
In class, for revision	1		33	
For individual reading	1		33	
For 'preparation', etc.	5		165	
Total	17		561	

Note. (*a*) It is found that the numbers of periods shown are divided almost equally between botany and zoology.

(*b*) The number of periods *in class* (excluding revision and individual reading) is 10 per week or 330 per year, that is, 660 in 2 years. The total of 650 in Table VI falls within this limit.

studied, principles must be examined more thoroughly and investigations conducted more deeply. The allocation of periods may well become that shown in Table V.

TABLE VI

The number of class periods shown in Table V (for the sixth form, i.e. pre-university pupils) broken down under topic headings,

First year						Second year					
Zoology			Botany			Zoology			Botany		
Topic	Theory	Practical	Topic	Theory	Practical	Topic	Theory	Practical	Topic	Theory	Practical
Amoeba	1	1	General plant biology	20	15	*Astacus*	4	6	Physiology	25	75
Paramoecium	1	1	Anatomy and histology	20	40	*Periplaneta*	2	6	Pteridophyta	6	12
Volvox	1	1	Ecology	10	20	*Anodonta*	2	4	Angiosperm	14	24
Hydra	1	2	Fungi	6	10	*Rana*	4	20	Evolution	6	3
Monocystis	1	2	Bryophyta	4	8	*Oryctolagus*	5	25			
Lumbricus	4	5	Cytology	1	1	*Columba*	3	10			
Distonum	1	1	Genetics	3	7	Physiology	10	15			
Ascaris	1	1				Ecology	5	4			
Taenia	1	1				Embryology	10	30			
Scylliorhynus	6	20									
Amphioxus	2	4									
Embryology	2	6									
Cytology	2	2									
Histology	10	20									
Economic zoology	2	0									
Distribution	2	0									
Ecology	4	6									
Evolution	10	10									
Other general problems	10	10									
Periods for theory	62			64			45			51	
Periods for practical		93			101			120			114

Periods for theory, zoology	107	Periods for practical work, zoology	213	Total for zoology	320
Periods for theory, botany	115	Periods for practical work, botany	215	Total for botany (2 years)	330
Total (2 years)	222	Total (2 years)	428	Total for biology	650

Note. See note (*b*) below Table V.

A more detailed analysis* than Table V may be of help to young teachers. This is shown in Table VI. Species, genera or even families may differ in various parts of the world, but the general relationships are a useful guide.

The content of the syllabus in any subject is affected by so many factors, some of greater importance than others, and some specific to particular situations, that an attempt to write a general review is difficult. The difficulty becomes greater when the subject under consideration, and its position in education, are in a state of rapid change. Such is the position in regard to biological education today, where change is so rapid that what is written at one moment may be out of date at the next.

In this chapter, the attempt has been made to indicate some of the factors which should influence the structure and content of the biology syllabus. In addition, examples of some of the older attempts at syllabus construction have been included. To keep pace with recent developments is not easy and a detailed syllabus, if presented, could only have a specific reference.

However, some guides to more recent developments will be found elsewhere. In Appendix G there is reference to the work of the Biological Sciences Curriculum Study Committee of the American Institute of Biological Science. In Appendix I there will be found curriculum and syllabus material from India and Ceylon, and a summary of the Vevey Seminar Biology Syllabus.

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* The figures are based on the author's experience and research.

CHAPTER V

THE PUPIL'S RECORDS; THE TEACHER'S EVALUATION

The tests and examinations a teacher sets, and his pupils' notebooks, reflect his attitude. Together with the other ways in which he tries to assess the quality and progress of his work, they depend upon his outlook, his approach to the course and his teaching methods.

Notes and records in biological work

It is usual for pupils to make notes, drawings and other records of the work they do, but it is seldom that any thought is given to the purpose of such records. Yet, without a clear idea as to their purpose, it seems doubtful if they can be appropriate. In the majority of cases these records are made, especially so far as the work of the higher examination forms is concerned, merely because they have to be submitted to examining boards. Sometimes these boards, perhaps a university senate for example, make demands of a kind which reduce the potential value of the notes to the student.

Note and record making, of any kind, in biological education, should be concerned with reaching understanding of the subject. It is an activity which should be considered, as far as possible, in terms of a *learner*, not of a teacher or examiner. To increase understanding is very different from improving memorization, and means that notes should be not only records of a descriptive type, but should also be both analytical and synthetic. In view of the somewhat varied type of material which the pupil produces as 'notes and other records of his work' it is necessary to consider it in more detail.

Written notes. These are far too often verbatim copies of what a class teacher has dictated. They are thus the work of the teacher, not of the pupil: yet it is the pupil who should be the central figure. How can we overcome this? First of all by improving our teaching, by giving it coherence, and by becoming more concerned with understanding and less with remembering. Next we must pay attention to such points as these:

(*a*) Notes should be an active response to a lesson or demonstration, or to reading, not a passive verbatim copy.

(*b*) They should present a general thesis arranged in a logical manner which fits in with an accepted plan of work.

(*c*) Notes should range beyond class work to field observations, experiment and collateral reading, and include not only 'set' work, but the results of enterprise and interest.

(*d*) They should be critical and constructive. The pupil should make notes of difficulties, points he does not understand, exceptions, ideas to explore further, and so on.

Pupils have to learn how to make useful notes. They can do this only if they receive adequate help and encouragement. In the lower forms such notes as are made are dictated by the teacher. Later the pupil uses these as a model for his own efforts under the teacher's guidance. It is likely to be several years before a pupil becomes proficient in the art of note taking.

Notebooks. The most frequent fault in pupils' records of school work is the failure to reflect the logical relationships of the subject-matter. This is because the records have not been planned from the start. All records, of whatever type and subject, must relate to a basic plan. This should be used as the framework of an index, which should be prepared and written out in the first one or two pages of the book. The pages of the book should be numbered and a suitable number of pages devoted to each topic, and the page numbers should then be recorded in the index.

Here, of course, the teacher's experience is essential to provide guidance as to how much space must be devoted to each topic. Even then, a pupil with special interests in a particular topic may soon exceed this allowance and be in danger of upsetting the carefully prepared index. This demonstrates the limitations of the usual notebook, bound with a limited number of pages and likely to suffer damage if many extra pages are interpolated.

The remedy for this difficulty is the loose-leaf system in which continuous expansion is possible, and in which logical relationships may easily and properly be preserved. The pupil has a permanent loose-leaf file, with an index and a series of specially arranged separation pages. Each of these has a projecting tab which bears a code number relating to a particular section of the index. In this work is permanently filed and may be continuously expanded or rearranged. For class work he merely has a series of loose leaves in a simple folder or large envelope, and these are transferred to the permanent file as they are used.

The most common objections to the loose-leaf system are:

(*a*) It is likely to become a 'lost leaf' system.

(*b*) The perforations are easily damaged.

(*c*) Dishonest practices are easier than with bound books.

Loss and damage are related, and are certainly likely to happen when the file has either a simple spring-back or if the pages have to be threaded on cord or metal strip. The most effective kind of file has rigid posts of metal which pass through the perforations and are closed with a screw cap outside the stiff external cover.

The dishonest practice most feared is that a pupil may 'show up' work other than his own. Any class teacher should be in a position to detect this, if he knows the work of his pupils as he should. And the task of overcoming it is bound up with wider issues than the type of notebook used.

A feature of the loose-leaf system which is usually neglected is that it offers a way of combining practical records with theoretical notes to make a sensible whole. Practical work, whether a record of dissections, microscope observations or laboratory experiments, is not a thing apart. To divide it from theoretical work, as the examining bodies usually do, is to ignore logic.

Biological drawings. The making of drawings in connection with both botany and zoology has not only long been an accepted technique, but has sometimes reached a stage in which proficiency as a draughtsman has been mistaken for competence as a biologist. This has come about largely because we have not cleared our minds as to the proper functions of drawing. In biology these appear to be:

(*a*) To ensure that the pupil looks at and examines the details of the specimen with proper attention.

(*b*) To provide avenues for learning through visual and kinaesthetic (movement) experience, in addition to the auditory experience of listening to the teacher.

(*c*) To provide a record of the work done by the pupil.

(*d*) To provide the pupil with material useful for revision.

(*e*) To act as a medium for analysis and synthesis, that is, to be a stimulus to thought.

The teacher and the pupil have to regard drawing, in its relation to biology, as a means of learning, not as an end in itself. This can be done only by those who give considerable thought to the whole process. To help the teacher make more effective use of drawing in relation to biology the following suggestions are offered:

(*a*) The real purpose of making drawings should be discussed with pupils, both individually and as groups, or in the class as a whole.

(*b*) Instead of asking only for representational drawings of the specimen, as seen by the pupil, we should take suitable opportunities to ask for other forms of response. Here are some possible methods of doing this.

(*i*) When the pupil has examined a series of sections, all cut in one plane (which he will draw 'as seen'), he may be asked to construct a diagram to show how a section might look if cut in some other plane.

(*ii*) When several specimens of one group have been examined in various ways (for example, three or four types of vertebrates), the pupil may be asked to construct a diagnostic diagram to show the general features of the whole group.

(*iii*) Copies of a prepared drawing may be provided and the pupil required to label the various parts by examination of specimens and a suitable textbook.

(*c*) When dealing with processes the pupil should make proper serial records. This is particularly necessary when dealing with dissections. The common procedure is to make a drawing of the finished job, but, while this is of value as a record of an end-point, it has less value for revision purposes. What is required, then, is not a picture of nerves or blood-vessels buried deep in the body of an animal, but a map, as it were, of the way to them. Such a map or route-card becomes available when the pupil makes step-by-step drawings of his dissection. (See Fig. 1, page 126.)

(*d*) We must encourage drawing from memory to illustrate written work and class discussions.

(*e*) It is wise to collect and show as many examples as possible of the effective use of drawing for illustrative purposes, even if it is not always in connection with biology.

There are other points to which attention may be given in the attempt to improve the standard and value of drawing in relation to biology. While it is not advisable to impose a standardized procedure on every pupil, it is desirable that everyone should be aware that:

(*a*) Drawings are best made with a fairly hard pencil, producing thin, sharp and determined lines.

(*b*) The effect of 'depth' is best obtained by making near lines thick and distant ones thin. There should be no attempt at shading.

(*c*) Where colour is used, a standard scheme should be adopted so that it helps in immediate identification.

(*d*) Colouring is best done with crayons.

(*e*) Labels should be printed clearly and with a definite line leading right to the structure named. (See Fig. 2, page 128.)

(*f*) Labels and pointers should be so arranged that the latter do not cause confusion by crossing each other. (See Fig. 2, page 128.)

(g) Drawings should be as large and bold as possible and an indication of magnification or reduction should always be given.

Some comments on evaluation

The customary method of evaluating success in learning and teaching is by examination. To the extent that the acquisition of new knowledge by the pupil is a desired result of education this is appropriate. Unfortunately, preoccupation with examinations often leads us to neglect other desirable outcomes of education, and we must not forget that examinations have defects of their own.

The teacher has little control over the public examinations for which his pupils sit. Over those he sets himself he has complete control, and it should be his aim to make them as perfect as possible. In attempting to do this a first point to note is that well-conducted examinations should not only provide an index of what pupils understand (as distinct from 'remember'), but also of the difficulties they experience. To be content with a mere list of marks and rank orders is to fail to use the examination as a means of evaluation and to be satisfied with its results as a form of descriptive label.

What can we do to improve our use of examinations? One important step is to consider carefully the type of question we set. Too often we concern ourselves only with details and ignore principles: we are content with artificial situations and ignore the setting as a whole. While we must indeed use some questions which demand little more than simple recall to memory, we should also use some which need real thought on the part of the pupil. Even when we attempt to do this we are sometimes guilty of not thinking sufficiently deeply ourselves about the problems involved. For example, a question which asks the pupil to describe the structure of the root and shoot of a plant is more simple than one asking for a comparison, because the latter should lead to the analysis of the differences between the two in terms of functions. However, pupils can learn to remember the data for the second just as they do for the first question. A more complex question does not of itself impose the necessity for thought. This can only be brought about when the question really sets a problem situation. This may be illustrated by taking a common question and proposing an alternative form. 'Describe some of the ways in which aquatic organisms are adapted to their environment.' In that form the question usually elicits a selection of what the pupil can recall and present in a limited time. It may be set in a very different way. 'Describe the kind of organism you may expect to find living in a fluid environment of constant temperature, with no light, little if any oxygen, and a high concentration of food materials readily available.' Many pupils, who are brought up to rely upon memory and to react to a kind of trigger stimulation, make little if any attempt to answer a question set in this form. Those who try to think seek an example of such an environment. They have to decide whether the environment postulated may be blood, the abysmal depths of the sea or the gut fluids of a mammal. Their conclusions may have, in one sense, as little value as the question itself, but at least they have gained by the experience of thinking.

It is well known that questions which demand answers of the essay type involve a subjective factor when it comes to evaluation by marking. At the same time such questions do give greater opportunity for the pupil to show that he can use his knowledge, marshal his facts and argue his case. In order to avoid subjectivity, considerable use has been made in recent years of 'new-type' questions. Some examples of these are given below as a guide for those teachers who wish to try out this type of testing.

Simple recall. This is neither more nor less than the old-fashioned 'quick-fire' question to which the answer is but a word or two.

1. An amoeba belongs to a group of animals called . . .
2. Vessels carrying oxygenated blood are called . . .

True-false tests. In this type the pupil is presented with a statement and is required to show whether it is true or false by underlining the T or F respectively.

1. An amoeba belongs to the group known as Porifera. (T. F.)
2. Arteries always carry oxygenated blood. (T. F.)

Among the disadvantages of this type are the potential ill effects of presenting inaccurate statements and the possibility of gaining marks by guessing.

Matching tests. Here the pupil is given two columns of data and has to match the items by writing the appropriate number in a space provided. It is usual to give more possible solutions than are needed. Otherwise marks may be scored by mechanical elimination.

'In the bracket spaces in Column 1 write the appropriate numbers from Column 2, thus showing who was responsible for the study of the subjects in Column 1.'

Column 1	*Column 2*
( ) Vaccination against smallpox	1. Carl von Linné
( ) The common system of biological nomenclature	2. Pasteur
( ) The conditioned reflex	3. Jenner
( ) Fermentation of yeast	4. Mecnikov
	5. Pavlov

Multiple choice tests. In this case the pupil is presented with a series of questions or statements, for each of which a number of 'answers' are also given. He is instructed to underline the correct response.

1. Vitamins are . . . mineral salts; enzymes; accessory food factors; germs.
2. Myelin sheaths occur on . . . neurones; arteries; muscle fibre; axones.
3. A *Testudo* is a . . . tortoise; turtle; elasmobranch.

Tests of this kind are quick and easy to use and mark, and can be made up in varying degrees of difficulty. But even the simple ones are not free of possible pitfalls, such as ambiguity.

The chief criticism is that, though free from subjectivity, they are too little concerned with understanding. In order to improve them it is now usual to make them more elaborate. This is generally done by presenting a detailed statement and then asking a series of questions on it. For example:

'In countries with well-marked seasons, where temperatures fall considerably in winter, many animals enter into hibernation in the autumn (the "fall" of the year). As an experiment a number of frogs were collected during the spring spawning period and taken into the laboratory. Some were at once placed in a cold water tank kept at 33° F., with a mud layer. Within a few days they burrowed into the mud and became inactive. The remainder were placed in a vivarium kept at 50° F. until autumn. Some were left in the tank and were still active in midwinter. Others were placed in a cold vivarium out of doors and these became inactive when the temperature fell to 33° F.

Below are 6 statements. Put a tick (✓) against those which are correct and a cross (×) against those which are wrong, in view of the description given above.'

1. Frogs can be made to hibernate at any time........(✓)
2. Hibernation is a response to season..............(×)
3. Hibernation is a response to temperature..........(✓)
4. Frogs can be made to hibernate by cooling.........(✓)
5. Frogs will hibernate in springtime................(×)
6. Frogs hibernate at 33° F..........................(✓)

This kind of test is an attempt to go beyond mere learning by memorization. It is concerned with the ability to argue from data to a specific conclusion. In other words it is a test of understanding.

Finding out about pupils' interests. Necessary as informational gains are, it is important to give attention to another of the very desirable outcomes of biological education: the development of new interests, attitudes and habits. These have been neglected in the past because the social functions of biological education have received too little attention. In almost all the countries which have not yet become strongly industrial and technical in their patterns of living, a majority of the people are directly dependent upon rural activities, and their problems have a biological basis. Educational facilities in these countries are rapidly extending, but there is a tendency to fail to inquire into the result of this expansion, except in terms of increase of literacy or the numbers of examination successes. If we fail to consider the social results of biological education we shall not make a maximum contribution to social progress.

Studies of biological interests have been made on a large scale. These show that there is widespread interest in biological phenomena among children, as among adults, though perhaps along different lines. As the psychological value to the individual of well-developed interests is accepted, it should be every teacher's responsibility to consider how far his work contributes to the development of interests. Therefore he needs to know something of how interests may be studied. This is a large and complex subject. All that may be given here is some indication of simple procedures, which may be adopted and, if necessary, adapted by any teacher.

(*a*) *Making a record of individual hobbies* (and out-of-school activities) among children, and arranging them in rank order of frequency to show which are more popular.

(*b*) *Analysing the contents of a 'question-box'*. This is simply a box into which pupils put slips of paper with written questions, etc. The subject-matter of the questions asked is then classified under suitable headings, such as animals, plants, physical objects, beliefs, customs, etc., and the relative frequencies, converted to percentage terms, are used as a guide to interests. (In one such analysis, dealing with 742 items collected in such a question-box over a twelve-year period, it was found that 61 per cent dealt with animal life.)

(*c*) *Using a questionnaire*. This should provide spaces for the child to record his age, name, sex, school and form, home address and father's occupation. The rest of the questionnaire should be given up to questions of the following kind:

(*i*) In what way do you spend most of your free time out of school?..
(*ii*) What is your favourite hobby? ....
(*iii*) What hobby or activity would you like to take up if you had enough money, time, and so on?......................
(*iv*) What sort of job would you like when you leave school? ....

Many teachers, when they first see proposals such as this, say that they do not understand how the results can possibly be of help. Experience with many teachers, however, has shown that such a study, even at a simple level, gives results which are of considerable value in helping the teacher to guide his pupils.

(*d*) *Using an inventory*. In this case the pupil is given a paper on which he records the basic data of age, sex, etc., and is then asked to underline in a list the things he is interested in. Here is an example of one such list:

'If you are interested in any of the hobbies in the list below put a cross (×) in Column A, and underline the particular hobby (or hobbies) which interest you most in Column B.'

Column A	*Column B*
I	Making models of: ships, trains, engines, aeroplanes, etc.
II	Using: 'Meccano', Constructor sets, etc.
III	Collecting: birds' eggs, butterflies, flowers, grasses, etc.
IV	Collecting: stamps, cigarette cards, pictures, etc.
V	Belonging to: Scouts, Guides, etc.
VI	Dress-making, making dolls, clothes, etc.
VII	Gardening, working on a farm, etc.
VIII	Keeping living things as pets.

By simple methods of this sort the teacher can find out a considerable amount about his pupils. By making such surveys at different times he can see whether any changes of interest have taken place.

Encouraging critical thinking. Apart from providing information, altering habits and helping to develop new interests, biological education should contribute to improved ways of thinking. It is widely agreed among science teachers that scientific education should provide a training in scientific method. Unfortunately it is often believed (as was said in Chapter II) that this is best done through physics and chemistry. Biology, being looked upon as less 'exact', or even as 'inexact', is sometimes considered less likely to give a training in science method. However, a pupil may be very exact, yet, if he is not critical in his thinking, he may not be scientific. It has already been pointed out that biologists proved particularly successful in 'operational research' probably because they were accustomed to handling data which is 'inexact', open only to a small degree of control, and very varied. Few of the pupils who learn biology will grow up to be scientists or biologists, but all have to face the ordinary problems of living. These problems, like those of operational research, are based on data which lack precision. Because it deals with data of that kind, biology may be an excellent medium for learning how to apply scientific ways of thinking to questions of everyday life.

The good teacher naturally wants to know how successful he has been in using biology to develop scientific ways of thought. This is a difficult task. To measure the effectiveness of ways of thinking is not easy. Further, to decide that improvements in thinking come only from the biological part of education would be quite unjustified. All forms of education should be aimed at achieving such improvements.

Although the teacher may find it difficult to measure, or even demonstrate, increased skill in critical and reflective thinking, he can at least take steps to encourage such thought. Thinking takes place in the face of a problem, but, unless the problem has meaning for the pupil, he cannot think about it effectively.

Therefore it is necessary not only to put the pupil in a problem situation (instead of merely telling him to 'learn page twenty-one', or to 'do exercise ten'), but it is also essential to ensure that the problem is meaningful to him.

Pupils and teachers must talk about problems, they must discuss what each problem means and plan ways of finding a solution. These proposed means must be discussed and criticized and alternatives considered. It is particularly important to consider the potential results of the means proposed, and especially to ask whether it can be decided that the results obtained are in fact due to the means used. Thus we are concerned with two kinds of understanding. Firstly, it must be ascertained that the pupil understands the *facts* involved in stating the problem under consideration. In other words we must be certain that the pupil has not merely learned in terms of remembering, but that he has learned in terms of understanding. Things which are understood are not only remembered, but can be used in new situations and in the construction of arguments. Secondly we must ensure that the pupil has gained understanding in relation to *method*. So far as most school work is concerned this means that he must appreciate the use of controls in experimentation, and the need to know how many variable factors are involved, and be able to try to vary one at a time. Further he should gain some degree of understanding of the operation of chance. A single result may be obtained by chance, hence an experiment must be repeated to ensure that it is concerned with a universal result and not with a chance detail.

It will be seen that this approach to the problems of teaching biology lays on the teacher not only the responsibility which is usually accepted, that of passing on information, but also another and more complex one. This is training in scientific procedures. In view of what has already been said it will be obvious that most teachers will not only have to reorientate their own attitudes, but set out with a new and specific problem in methodology. Some of the steps which this involves must now be considered.

Problem-setting can no longer be dealt with only in terms of book exercises. It must be dealt with in terms of reality and experience, and these must be in terms of the pupil and not the teacher. This is why stress is laid in this book on the *project method*: it is concerned not with minor details but with major concepts, with comprehensive problems calling for the integration of several forms of knowledge and the application of several kinds of skill for their solution. Moreover, as is so characteristic of the history of scientific advance, the project calls for teamwork, for collaboration, for shared responsibility. It cannot start without a classified understanding of the facts involved. Nor can it proceed without a planned procedure already subjected to critical analysis.

The understanding of facts can be tested by discussion, by using the short type tests mentioned on page 101 and by exploring the extent to which the pupil can group his facts (which are isolated details) into major concepts or universals. For this purpose it may be necessary to develop exercises of the kind illustrated in the following example, which may have to be modified in any particular area.

'Here are three statements which are generally accepted as true. They have been labelled A, B and C.

A. The work of the Department of Medical and Sanitary Services helps chiefly to prevent infectious diseases.
B. Personal hygiene aims at preventing illness.
C. Habits and customs persist for a long time, although social conditions may change rapidly.

Here is a series of ten statements. Put A, B or C beside any which you think illustrate one of the three general statements given above:

1. Few people are careful to boil and filter drinking water. ....
2. The amount of money spent on patent medicines is increasing ....
3. Malaria has been greatly reduced by DDT spraying....
4. There are many young children in employment in the capital city ....

5. The trains are often greatly over-crowded............
6. It is wise not to walk barefooted ....
7. Many people still go to witch-doctors, magicians, etc.....
8. Amulets and charms are used to try to cure illness......
9. People eat too much starchy food and too little green vegetable.................................
10. Increased use of covered drains has cut down typhoid...'

The aim of such a test is not to find out how many answers are right or wrong and to give marks for them. It is to use the exercise to show the relationship between statements of detail and statements of universals. Its quality and value emerge only if it is used properly. This means using discussion and criticism. For example, statement 3 is true. If a pupil writes 'A' against it, this should be discussed. The 'Department of Medical and Sanitary Services' may have done the DDT spraying, but malaria is not an infectious disease. In brief, pupils have to be exercised in critical thinking.

Estimating social effects. In many areas of the world the whole economy and pattern of living depend directly upon agriculture, fishing, and animal breeding in some form or other. In many countries an immediate problem is to achieve self-sufficiency in food production. It is essential for more people to engage in productive work and for them to be sufficiently informed and interested to adopt better methods of cultivation. This shows the importance of trying to evaluate our biological education. We must try to find out whether it is contributing to social needs as a whole. Unfortunately such studies are, so far, few in number, but those we have show conditions which should make every teacher think carefully about his subject-matter and methods. We may take as an example one country which is basically dependent upon a rural economy. Its agriculture is so heavily devoted to plantation crops, which are bound up with world economy, that food production is not enough to meet the country's needs, and to step this up is the most urgent social need. Studies of interests (hobbies, school subjects and vocational ambitions) show the following points. While 63 per cent of the gainfully employed are in productive work, only 23 per cent of school children want to enter productive occupations. 52 per cent of school leavers want to enter the professions, which require only 6 per cent of total man-power. Biological interests are not highly developed. Less than 5 per cent of a sample of nearly fifteen hundred school leavers showed any wish to study rural science, which is absent from the school curriculum because it is not a subject for the examination (School Certificate or General Certificate of Education). No student entering the universities in the year of the survey expressed interest in farming or plantation work as a future career. Such a state of affairs is serious.

Unless biological teaching is seen in relation to facts of this sort, and can help to guide education along more socially necessary lines, it has comparatively little value. Moreover, unless surveys of interests are carried out by teachers, facts of the kind given above remain undisclosed, and biology continues to fulfil a purely academic purpose.

If biological education is to affect society it must change the habits of people as individuals and as communities. The position may be defined in terms of a few simple examples: changed habits in regard to the boiling and filtering of water may reduce many kinds of intestinal infection; changed excretory habits may reduce the incidence of hook-worm infestation; altered feeding habits may improve health. These are simple statements which may be multiplied. If they are made effective they may have vast social consequence. Biology teaching, health education, domestic science, and so on, dealt with only in academic terms, may have no effect on habits, and even if they have, the extent of their influence may be unknown. The biologist should therefore give some attention to this aspect of his task, even though he finds himself concerned with the habits of parents rather than of pupils.

It was exactly this attitude that Professor Collings* took up, some twenty-five years ago, when he estimated the results of his teaching, not by testing his pupils, but by studying their parents.

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* In the United States of America.

His work was carried out in a small, rather isolated, farm community, in a village with only two schools. First he made a survey of habits and conditions of living, frequency and types of illness, the extent to which welfare and advisory services were used, and so on. Then, in one of the schools, he put into operation a project which had a strongly biological and social bias. After an experimental period of four years he repeated his survey and compared the conditions he found among the parents of the children in his project-school, with what they had been before the experiment began and with the parents of other children.

To describe the results obtained in detail would be impossible, except in a lengthy book, but some of them can be shown very shortly in tabulated form. Table VII shows some of the ways in which the behaviour, habits and actions of parents changed through the indirect action upon them of the new kinds of teaching experienced by their children. These figures deal with

TABLE VII

Some effects of improved education in biology and rural science on parents and children in a rural community in U.S.A.

Criteria	C	E	
Home leisure reading	5	85	Conditions among pupils
Community activities	1	100	
Doing project work in vacation	5	69	
Using health habit at home	3	81	
Decrease of illness among pupils	25	35	
Reading from bulletins	3	96	Conditions among parents
Testing seed corn	21	48	
Testing milk of cows	17	58	
Using improved stock	7	31	
Using fly screens	6	41	
Improved sanitation	15	72	
Decrease of illness	4	20	

The figures are percentages. E = experimental school using the new curriculum and methods. C = control school in which the older and more traditional methods were continued. The figures show conditions at the end of the 4-year experimental period, and the differences are considered to be due to the different curriculum and methods.

changes in homes where literacy existed already, and where the standards of living were higher than in some places. There is no reason to believe, however, that changes of similar kinds may not be brought about in any community. Nor can it be denied that any educational methods which improve agricultural procedures, health habits and hygienic precautions, widen interests, and encourage the use of available community welfare services, are worthy of trial, when such progress is so greatly needed.

The figures speak for themselves. If, in the many areas of the world where hook-worm is common, where fly-carried disease is prevalent, or where little care is taken to use and improve good breeding stock, such changes could be brought about by improved biological education, social progress would cease to be a hope and become a reality.

At the beginning of this chapter it was pointed out that one aim of biological education should be to emphasize the unity of the organic world. Also it was stated that biological principles may be related to mankind, in terms of the individual or of the society in which he lives. From these statements there follows a possibility to which very little attention has yet been given: the use of biology as an instrument to break down inter-group prejudice and so to contribute to international understanding.

This is a problem which, so far, has been thought of mainly in relation to history, geography and other forms of social study. While it may well be that these subjects, so much more directly concerned with Man, can make a more direct contribution than biology, it is nevertheless important to consider how this subject also may help.

Studies of inter-group attitudes, of what one kind of people think of another, have shown how some think themselves 'superior'. This 'superiority' is based upon many criteria, such as colour, physique, intelligence, athletic prowess, endurance and the like. It is indeed true that these are real characteristics and that some of them do distinguish different kinds of people. The fault lies in assuming that one particular set of characteristics is in some way superior to another set.

While it may be true that little is known about some of these characteristics, at least it is possible for the teacher to discuss them in biological terms. For example, an animal may be adapted, by some kind of specialization, to live in a particular environment. In another environment quite a different adaptation is found. Both are accepted as examples of the harmony between form and function, between organism and environment. It should be possible to treat colour, or any of the other distinguishing features, in the same way. Here the teacher must make it his task to show that different peoples are fitted for different environments, and that only the possibility of travel has brought them together and allowed of a false claim for the superiority of one over another.

It may well be found that a claim for such superiority may be based upon tests of intelligence. While it is true that certain peoples apparently perform better than others on such tests, it must not be forgotten that these tests are based on particular backgrounds. In very simple rural environments the tests may be almost meaningless, because the problems are irrelevant. An intelligent response in such conditions is impossible, not because of differences of a psychological kind, but because of cultural differences. The position may perhaps be illustrated by pointing out that a city dweller and a hill tribesman would be equally lost in each other's environment.

To suggest a problem worthy of attention, and to propose some elementary ways of dealing with it, does not, however, indicate ways of evaluating success. In what ways can it be shown that some special treatment of race prejudice along biological lines has in fact reduced the degree of prejudice? An attempt to give specific guidance on the measurement of prejudice would not only go beyond the confines of biology method, but would involve entering into very complex fields in social psychology. It is, however, possible to give a brief description of one very simple method.

It is well known that people belonging to one group have a collective opinion about those in another group. This opinion, often based upon very frail evidence, is called a stereotype. In any school class each pupil has a stereotype of people of other kinds. If each pupil is asked to write down what he thinks are the chief characteristics of two or three other groups, say of the English, the Russians and the Maori, it is possible to collate all the statements into a collective stereotype. It is found that some characteristics are mentioned several times, others only a few times. It is also found that some characteristics are acceptable, others less acceptable. It is also found that pupils have a preferential view of the group to which they belong, a less complimentary view about other groups. It is just that which the biologist hopes to attack through his special programme of studies. He hopes to reduce inter-group tension, to make one group see another in a more favourable light.

Thus there are three obvious stages in an attempt to reduce prejudice. Firstly, to make a collective picture of stereotypes of several different peoples, including the group to which the pupils belong, and one or two attitudes which it is hoped to alter. Secondly, the teacher conducts his special programme, the social biology of man, showing the essential unity of peoples. This may include many aspects and may last, perhaps, a whole term. Thirdly, the collective stereotype is studied again and, by comparing the distribution of favourable and unfavourable items in this and the first stereotype, it may be possible to estimate to what extent there has been a reduction of prejudice.

Other methods which may be used, but cannot be described here, are social distance scales, sociometric tests and attitude scales.

It may be wise to note that any attempt to show the unity of mankind, in an attempt to break down prejudice, must not deny the existence of diversity. There appear to be good grounds for thinking that different peoples have different gifts. This does not mean that one is therefore better than another, but that each has become adapted to a particular environment.

Finally, it should be seen that methods of approach, the objectives of biological education and modes of evaluation go hand in hand. If one aim is to develop better ways of thinking, then the methods of teaching must lead to experience in thinking, and not only to memorization. Unless this relationship is seen from the start, the programme of biological education cannot be planned as a whole. If it is not planned as a whole it cannot achieve maximum results.

Pupil's difficulties

This chapter ends with a brief discussion of some of the pupil's difficulties, as these in turn become problems for the teacher.

The pupil's attitude to the syllabus. Teachers often ask 'What can be done about the pupil who says "but it is not in the syllabus"?' To teach biology in such a way as to obtain its maximum value it is necessary not only to rearrange the materials of the syllabus in relation to special needs, but also (though perhaps not often) to stray outside them. The reason for doing so may be to provide other evidence, to extend experience and so to increase understanding and make learning easier. The pupil too seldom sees the matter in this light. To him it is an unwarrantable addition to an already overloaded syllabus. This attitude, particularly common in some countries, arises from the confusion between knowing and remembering. A long verbal tradition, in which learning by heart has been the chief part, has left its mark on education today; so the pupil seeks to remember, and does not try to understand. Teachers themselves, as part of such an authoritarian social structure, demand conformity and acceptance; almost never do they seek criticism. Thus the pupil becomes conditioned to learning as memorization, not as critical or creative thinking. Moreover he, and his parents, too, are well aware that examiners tend to be concerned only with remembering, and that the competition to get work is extremely severe. In such a situation any attempt to go outside the syllabus must appear to be risky and unjustified.

The rewards of extra-curricular activities are well known to those who have had experience of entering pupils for open scholarship examinations at the major universities. Such pupils bring to their work a wider outlook, a greater knowledge and a keener interest, and they are correspondingly more successful as candidates and students. To anyone with any idea of the function of interest as a motivator of effort, this is to be expected, and everyone knows that effort is one of the ingredients of success. Thus, in the interests of achieving better standards the teacher should encourage extra-curricular work through the school natural history society, by voluntary work in building up school museum collections, and so on.

Diagnosis of pupil's difficulties. Although most teachers realize that it is necessary to consider in advance such problems as the arrangement of the time-table, the availability and supply of specimens and the like, few realize the need to be prepared for other difficulties, especially those likely to be encountered by pupils. Yet the successful development of a school biology course depends upon the degree to which this particular group of difficulties can be overcome. They cannot be overcome unless they are diagnosed and defined. An inquiry was made* amongst sixth-form (pre-university) pupils, of both sexes, in order to determine the major difficulties in learning biology. Here is a brief analysis of the results.

In practical work. 1. Difficulty in understanding the relations of internal structures in solid bodies in three planes.

2. Inability to translate flat pictures into solid objects.

3. Failure to understand how various organs work because of lack of attention to function.

4. Inability to remember 'how to start the dissection' or the order of procedure in later stages.

5. Lack of skill in dissections due to insufficient time for practice.

6. Inability to remember names and technical terms owing to the complicated terminology.

7. Inability to identify 'spots'. (Often when able to name them, unable to offer reasons for the identification.)

8. Inability to make drawings except those of a purely representational kind.

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* By the author.

9. Inability to understand the principles of the use of a microscope.
10. Reliance upon memory rather than understanding in the preparation of microscopic slides.

In theoretical work. 1. Trouble with terminology, accentuated by use of many synonyms.
2. Failure to follow simultaneous developments in embryology. Confusion about true time relations as a result of having to study one system at a time.
3. Difficulty in appreciating the essential differences between various evolutionary theories owing to lack of detailed knowledge.
4. In spite of finding it easy to remember the simpler laws of heredity, inability to apply them to numerical problems.
5. Frequent confusion in cases of analogy and homology.
6. Inability to formulate principles from detailed facts without considerable help.
7. Still more difficulty in formulating principles for biology as distinct from those in the separate branches of botany and zoology.

It is probable that pupils in different environments may also experience other difficulties. This is a point which each teacher must explore for himself. Having done so his next step is to seek means of overcoming the difficulties. A few suggestions are made here.

Terminology. Difficulties arise partly from the overloading of the subject with unnecessary terms, partly from lack of knowledge of the derivations of the terms and partly from the existence of synonyms. The steps to be taken are:

(*a*) To reduce the use of technical terms to a minimum; and refuse to believe that a pupil knows more about a structure when he gives it a long rather than a short name. (Many pupils find terminology confusing because the textbooks chosen are too difficult and too advanced for the particular stage of their work.)

(*b*) To take every opportunity of finding out the meaning inherent in technical terms. Scientific terminology is international and largely based upon Latin and Greek. When western classical languages were part of the cultural equipment of all educated people, the learning of a specialized terminology was by no means difficult. Nowadays, when the study of western classics is on the decline in the West, difficulties with terminology are increasing. Elsewhere, there is a tendency for national sentiment to revive the use of indigenous languages and their own classical antecedents. Thus pupils are faced with even greater language problems. Try, therefore, to keep technical terms simple and, as far as possible, to explain their derivation.

(*c*) To construct tables of synonyms, and at the same time recommend certain usages, explaining why these are preferable. All such tables should define meanings and show derivations.

Spatial perception. In attempting to understand the morphological arrangements of an organism, three-dimensional perception is important. It is needed for understanding structures which can be seen or dissected as a whole, and even more so in the case of textbook pictures, and of microscopic objects or embryological specimens, which are studied in sections. Though the section cut by the microtome or razor is three-dimensional, it is so thin that it tends to be regarded as two-dimensional. Thus the basic difficulty is that of translating from one frame of reference to another. Pupils may be helped by methods such as these:

(*a*) When they have examined a series of cross-sections ask them to draw not only transverse sections, but also a diagrammatic longitudinal view.

(*b*) Keep a supply of clay or plasticine available, so that a structure may be modelled, as well as drawn.

(*c*) Pupils should make use of stereograms (drawings to which an illusion of solidity is imparted by the use of perspective).

(*d*) Make and use enlarged models which may be taken to pieces, or which have part of the surface cut away to show the internal structure.

(*e*) Over-lay diagrams may be used.

(*f*) Ensure that there are plenty of specimens and materials so that they may be seen and handled often enough for pupils to become familiar with them.

(*g*) Encourage the making of simple diagnostic models to show how structure is related to function.

In some places, for example where manual work is supposed to give low social status, there is often antipathy to practical work of all kinds, and it tends to be neglected in the schools. Moreover, for cultural and economic reasons there may not be the same development of constructive and experimental hobbies as in certain other countries. Thus it appears probable that three-dimensional perceptual abilities are less highly developed. The methods suggested as a remedy for this weakness must therefore be stressed. (Details of putting them into practice, in model-making, drawing stereograms, and so on, are given in Chapter VII.)

Some problems in thinking. Scientific thinking and the relations between details and universals have already been discussed. Pupils differ from each other in regard to these skills, because these are the fundamental aspects of thinking and are reflected in variations of ability. As a pupil becomes older and more mature, his ability to think becomes greater, so he starts with easy work and progresses to that which is difficult.

Teachers should try to help pupils to improve their ability to think by discussing with them, in an elementary manner, the nature and structure of knowledge and ways of thought. In particular, they should be helped to understand the nature of evidence and its shortcomings, how observations are assembled to form an hypothesis, how this can be tested and checked, and finally accepted or rejected. It is important that the nature of the 'experiment' should be understood, as well as the function of the 'control', and the need to vary only one factor at a time.

Some kinds of practical work in biology, especially in ecology, physiology and school gardening, offer an excellent opportunity for experimental work of a kind suited to the discussion and demonstration of scientific method. Such an opportunity should be put to good use. Thus readings and records should be pooled and the means calculated. Abnormal variation from the mean should be discussed, especially to find out whether it is a function of the material or process, or results from faulty procedure or mistake in observation, recording or calculation.

Attempts to inculcate scientific methods of thinking can be carried further by reference to the historical development of scientific ideas, with regard, for example, to spontaneous generation or the causes of disease.

In brief, the teacher of biology should be concerned not only with enlarging his pupils' knowledge of the subject, but in developing their ability to think about it.

CHAPTER VI

PRACTICAL WORK IN BIOLOGY

The importance of practical work

Biological science should be taught primarily as a practical subject. When treated as a largely theoretical subject, as it is by far too many teachers, pupils suffer in two ways. Firstly, they lose in understanding, training in skill and in the relation of the subject to everyday life. Secondly, there is no opportunity to emphasize the general value of practical work in a sphere where caste or status signify very little or nothing. Both losses are to be regretted, but the second may be the more serious.

In many tropical areas caste is a feature of social organization. The manual worker is often held in low social esteem and is poorly paid. Where this is so the emphasis upon 'white-collar' occupations is often pronounced, and pupils and parents tend to be averse to practical studies in schools. Yet in such regions there is, in general, a growing demand for practical workers and technicians; so the unwillingness to follow practical courses, for example in carpentry and metal-work, is a threat to social progress. Physics and chemistry are more readily accepted than biology because they are free of caste stigma and are usually preliminaries to the study of professional courses. Biology, too, as related to medicine, is accepted in this way. But it also has a relation to other occupations, such as agriculture. Thus the subject may well be of social value in breaking down popular prejudices.

In order that the social value of biology may be exploited as fully as possible, the relation between biological ideas and social phenomena must be made clear. This relationship must be made real. It must therefore be studied in practical and realistic terms. The community and its problems must be used as the raw material of observation and, where possible, of experiment. One aspect of social education, derived from biological sources, is the development of good habits, in regard to health, for example;

but habits are acquired only through practical experience, and not by theoretical studies.

It must be noted that the distinction between theory and practice is, to some extent, artificial. We must ensure that both are conducive to thinking. Practical work should be a challenge to creative thought, and not just a process of looking, drawing and doing. It must be undertaken in order to solve a problem. The teacher must make sure that practical work is a problem-solving task, put forward in terms of a problem. Unless pupils are faced with a problem to solve, as well as a dissection to make or specimen to draw, they are working solely at the physical level.

The time needed for practical work

Although there is fundamentally no difference between the mental processes involved in practical as distinct from theoretical work, there is an accepted difference in procedure. The question at once arises: what proportion of the available time shall be given to each kind of work? Remember that:

(*a*) Time is needed to prepare material *before* the practical period begins.

(*b*) Pupils also need time for preparation, for example, to sharpen scalpels or get out apparatus, usually *after* the practical period begins.

(*c*) Various experiments and practical procedures occupy different lengths of time: thus air-drying of soil samples, or growth studies, take an unavoidable amount of time.

(*d*) Time is needed to demonstrate how to set up apparatus, how to dissect, and so on. Experience and skill may shorten the time required, but not beyond a certain limit.

(*e*) Pupils work at different rates. If care is not taken the progress of the class as a whole is decided by the working rate of the slowest member.

(*f*) There is a time factor in learning which appears to be related to neural processes and to the maturation of experience. Moreover, some ideas take longer to develop than others.

(*g*) There is a psychological mechanism in learning whereby a series of short repetitive experiences is often more effective than a single experience occupying the same time.

There are two further points to be noted when considering the organization of practical work:

(*a*) The total time available for biology might be devoted wholly to theory, or wholly to practical work. The arguments already presented make the first unacceptable; and for various reasons few teachers would accept the second. Experimental studies have shown that the question is more complex than it appears, and that the teacher's approach is of overwhelming importance. Where he is able to stimulate thought and make practical work a highly mental activity it becomes very effective, but when he fails to do so it is far less rewarding. Thus a hard and fast rule, true for all circumstances, cannot be laid down.

(*b*) Unavoidable preparatory work takes up a proportion of *every* practical period; and the longer the period the less the proportion of time so required.

Bearing all this in mind, each teacher has to make his own decision, and be ready to modify it in the light of experience. Many teachers, faced with the same problem, decide that it is better to devote more class time to practical than to theoretical work, as suggested by Tables IV–VI, page 92. Table VI shows how practical work, in both zoology and botany, may well be given approximately twice as much time as theory.

Organizing the work of the practical class

If pupils are to be mentally active while doing practical work, the teacher should arrange his work with this purpose in view.

(*a*) All preparatory work should be completed before the practical period begins. If pupils have to wait while this is done, it wastes time and reduces interest, attention and discipline.

(*b*) Pupils should know beforehand what work they are to do and should come to the class prepared with appropriate instruments. (If these are provided by the school, they should be ready and distributed at once.)

(*c*) Instructional material, such as work sheets and diagrams, should be ready for immediate use.

(*d*) The teacher should *demonstrate* what is to be done, but the demonstration should be a give-and-take affair. Its purpose must be defined, its method explained and its results shown, but during the process itself there should be the cut-and-thrust of question and answer.

Some processes are too complex or take too long to be demonstrated as a whole at one time. In such cases a brief description of the whole process should be given, convenient stages should be noted, and the first stage demonstrated. The pupils carry out this first stage. The second stage is then shown and performed by the pupils; and so on until the operation is complete.

In demonstrations of all kinds there are three points to which attention should be given:

(*i*) The pupils must have a clear understanding of the purpose of the work.

(*ii*) They must understand the methods used, the order of procedure, and so on.

(*iii*) They must make records of the procedures as well as of the results.

(*e*) There must be adequate opportunity for pupils to become thoroughly familiar with the work through revision of various kinds.

(*f*) Throughout all practical work the link with theory must be stressed at every opportunity.

(*g*) Pupils should extend and consolidate their knowledge by teaching each other, by holding 'quizzes', etc., since trying to teach is a very effective method of learning.

(*h*) Group work should be encouraged, but all members of a group should participate so that the more exciting or exacting work is not monopolized by one or two individuals.

(*i*) The teacher must be an active participant. It is not enough to demonstrate a process and then merely wait for it to be repeated by pupils. He should go round helping, questioning and encouraging, and must try to give attention to every member of the class.

(*j*) The teacher must also try to let pupils do extra practical work in their own time. This should not be confined to normal syllabus work, but extended by subsidiary experiments, and so on.

(*k*) Records, models, prepared specimens, etc., should be preserved and used to build up a teaching collection.

(*l*) Pupils should be taught how to care for apparatus and instruments, and a regular routine for inspecting and checking should be arranged. Facilities must also be available for repairing apparatus and for keeping all kinds of equipment in good condition.

(*m*) The relations between laboratory experiment and field observation should be explained and explored as fully as possible.

(*n*) Practical work necessitates a certain amount of moving about and talking. These must be allowed, but should not become unruly. Reasonable discipline is always required for good work, and we have to remember that in some kinds of practical work there may even be potential danger.

(*o*) Every teacher should be aware of potential dangers. Appropriate safety precautions must be taken: for example, in the handling and storing of chemicals, in setting up and using apparatus, by correct procedure in the use and care of instruments, etc. A knowledge of first-aid is essential, and there should be a simple first-aid kit ready for immediate use.

In the teaching of zoology there are a number of problems which present difficulties not only to the pupil, but sometimes to the inexperienced teacher. Some of these receive particular attention in the following pages.

Animal dissection

It has been mentioned that among some peoples there is a reluctance to take animal life in any form. There are also various attitudes towards dissecting animals, ranging from physical repugnance to an idealistic unwillingness to destroy the harmony of a once-living form. The former is not uncommon, but is usually overcome by time and patience. There should be no attempt to force a change of attitude. Even careful argument does not always succeed, because the attitude is not based on reason. The second problem is more difficult. It may perhaps be approached through an argument based upon values, or relative values; but among those to whom all life is sacred this often fails. Sometimes example and social pressure, unconscious and implicit, never a direct explicit attack, may overcome such opposition. Finally, antagonism may always persist, yet be overcome by the pupil at the expense of a guilt complex, or it may never be overcome. In such cases the pupil should be encouraged to choose other subjects of study. He should not spend his time preparing for a career, for example in medicine or veterinary science, which he will probably never enter.

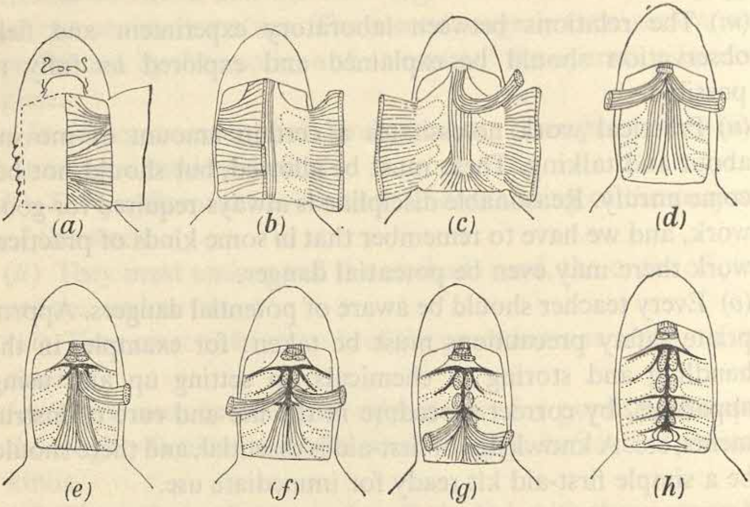

FIGURE 1.—Serial drawings to show the various steps in the dissection of a dogfish ($\times \frac{1}{4}$)

Comparative anatomy, and much of general physiology, can only be understood through dissection. But without good teaching the importance of dissection remains unrealized.

Dissection must always be demonstrated by the teacher, who must explain, step by step, what is being done and why. It must be possible for every pupil to see what is being done. Thus it is almost always necessary to work with small groups and to repeat each process for each group. The teacher should also demonstrate how to make records and drawings of dissections. These often consist solely of a final drawing of the completed work, showing, for example, the cranial nerves of a dogfish, which, though essential as a record of anatomy, has little value as a record of *how* the work was carried out. It does not, for example, show the route from the skin to the required structure. Hence it is not much use for the revision of method, as distinct from morphology. The pupil needs a stage-by-stage record showing each step of the process and the results of each step, so that he can look at his book later and recall the whole sequence. (See Fig. 1.) A particular value of this approach is that it encourages true dissection, the removal of morphological units, such as muscles, for example, instead of the haphazard cutting up of the cadaver which is so common.

For the more lengthy and complex dissections, mostly vertebrate, it is also useful to have the following aids available:

1. A series of specimens, each dissected to a particular stage, to provide a complete guide.
2. Labelled diagrams, based on each of the stages in the dissection, showing 'how to do it' rather than the results of each action.
3. A model, or a series of models, on as large a scale as possible, to show any particularly intricate stage.
4. A few examples of pupils' dissections, preserved from former classes.

Although preparation of these teaching aids takes some time, it is time well spent. Moreover, pupils can help with the work, and thus gain skill, confidence and knowledge.

Pupils should preserve their own dissections until the end of the course, so that they have available, for revision purposes, not only their notes, but the completed dissection. Small specimens may be preserved in large test-tubes (boiling tubes), while for the larger ones empty jam-jars, etc., are adequate. (Museum jars are very expensive and quite unnecessary.)

Lastly, good dissection requires not only skill, but sharp instruments. The practice of buying standard sets of instruments,

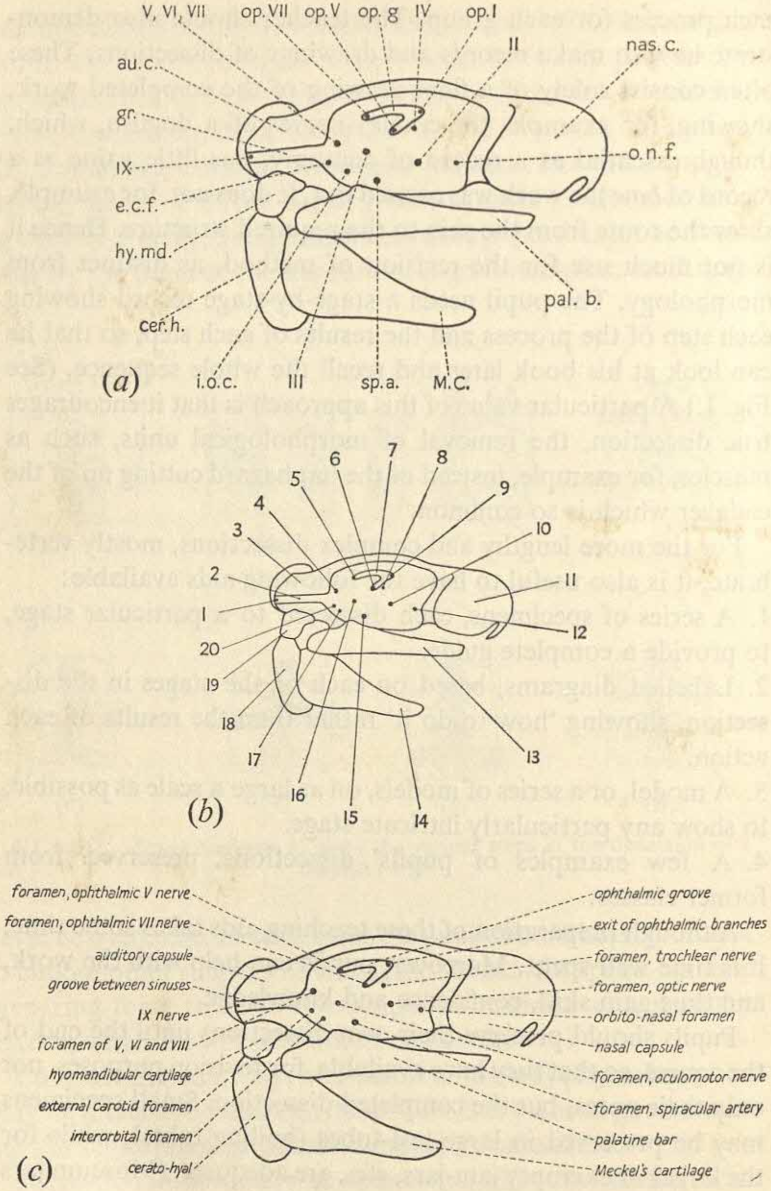

FIGURE 2.—Various methods of arranging the 'labelling' of diagrams
(a) A biological diagram labelled with abbreviations
(b) A diagram with a numeral labelling system
(c) A diagram 'keyed' with tabulated labelling

though convenient, has drawbacks. It is usually preferable to buy specially selected instruments and to make a roll-up cloth container or 'hold-all' for them. A typical collection of the kind suitable for a sixth form (pre-university) pupil is:

Scissors;	large, (8″)	1 pair
	medium, (6″)	1 pair
	fine, (4″)	1 pair
Scalpels;	large blade, rounded	1
	medium blade, rounded	1
	fine, pointed	1
Needle scalpels (made from steel knitting pins);		as required
Needles;	triangular, stout	1
	circular, fine	1
	blunt (seekers), straight	1
	blunt (seekers), curved	1
Razor;	botanical, flat on one side	1
Forceps;	large	1
	medium	1
	fine, straight	1
	fine, curved	1

Stainless steel instruments are preferable. They should be washed and dried after use. Ordinary steel should be given a light coat of oil or 'Vaseline' if it is to be unused for a long period. All pointed tips should be protected by small corks or by pieces of rubber tube slipped over them, but they must be greased to prevent rusting.

For some purposes, for example fine dissection, it is useful to make special instruments from steel knitting needles. The end is heated until red and hammered roughly to shape. It is next filed to the exact shape required. This process renders the metal soft and it cannot hold an edge. It must therefore be re-tempered by heating to a bright cherry-red and then plunged into cold water. If it is not hard enough this must be repeated until it retains the edge ground on to it. For making very fine blades a stout darning needle or crewel needle may be used.

Instruments are dangerous when blunt, and are responsible for poor workmanship. The proper 'stones' are necessary to keep them sharp. The most useful stones are:

1. A medium texture carborundum stone of about 8 by 2 inches, for use with medium oil.
2. A stone of the same size, but very fine texture, for use with very thin oil.
3. 'Slips', i.e. small wedge-shaped hones, which are used dry, or with oil for 'touching up' and for small home-made instruments.
4. A razor stone, about 8 by 2 inches, of extremely fine texture. The type used with oil is usually most satisfactory.

Such stones must be well cared for. There are two basic rules:

1. Each stone must be used only for its specific purpose.
2. Each stone must be kept in a wooden protective case, which is opened only when it is to be used, and is then closed immediately after use. (Damage by dust and grit is thus reduced to a minimum.)

Observance of these rules does not protect a stone against abrasion caused by allowing the point of a scalpel to 'dig' into the surface. Every pupil should be trained to use a stone, and the theory of the process should be explained to him.

All blades, other than those of scissors, are sharpened by pushing them across the stone with the cutting edge in front. With scalpels the motion is part of the arc of a circle whereby the blade sweeps forward with a slight drawing motion. The blade should not be parallel with the surface of the stone, but lifted the least possible amount to keep the back of it out of contact with the surface. By this means the section of the blade has two angles each side. Such a motion tends, in time, to hollow out the stone. If the stone is used so that each long edge in turn is nearest the operator its useful life is prolonged.

In sharpening a razor the process is more complex:

1. It is ground on the razor-stone with the blade flat on the stone. By this means the flat side of the blade remains flat. The hollow-ground upper surface is very narrow and cut at an angle to the lower surface. In use, a thin section is thrown upwards slightly, preventing it from crumbling under pressure caused by

dragging due to friction. The blade is pushed from end to end of the stone with a slight, arc-like, drawing action.

2. It is stropped on a leather strop, which may be limp (i.e. suspended from a hook), or solid (i.e. glued to a wooden base).

3. It is polished with rouge powder on a solid glass slab, with actions similar to those for grinding, but made much more gently.

In sharpening scalpels or razors, and whether using stone, leather or glass, there is a basic rule to be observed: at the end of each stroke the blade must be turned over, not on its cutting edge, but on its *back*. If it is turned over on its cutting edge, much of the good effect achieved by the sharpening stroke is lost because the newly made edge is used as the pivotal line of the turn. Sharpening a cutting edge may be thought of as a process of aligning and straightening small pieces which, under the strains of cutting, become bent over and form a 'burr'.

The teaching of physiology

Physiology cannot be properly understood without considerable practical work. There has been a tendency, however, to treat it in theoretical terms, and merely to describe experiments, without either demonstrating them or allowing pupils to perform them. As a result, pupils have paid insufficient attention to function. If such methods are allowed to continue biological education will have little social significance.

Animal physiology. The physiology of animals has often been taught less well than that of plants. This has not always been due to the problems of beliefs and traditions. It is suggested that many of the difficulties may be overcome by following a scheme such as that outlined here.

(1) The animal must first be considered as a whole. Animals are living organisms and a study of their habits and behaviour is a highly desirable corrective to excessive laboratory study of dead specimens.

Part of this work is purely observational and part is experimental. Both parts offer opportunity for work in the field as well as in the laboratory. An approach of this kind is necessary for a proper appreciation of ecology. Attention may be given to the following:

(*a*) Simple observations on animal habits and behaviour, response to stimuli, selection of habitats, etc. It is under this heading that 'bird watching' may be placed, a natural history hobby which is highly developed in the schools of some countries, and which is followed by many more than those who are specializing in biology. Opportunities for such work are greater in tropical countries, where so little is yet known of the *life* of the fauna. Local conditions determine what may be done, but the following examples may be regarded as typical.

The relations between the common crow and the fruit bat. (These animals live very different lives, but in some areas they use the same trees for roosting, though at different times of day or night. A number of problems await exploration.)

The habits of the wall-lizard (gecko). (The gecko is very common, yet is the source of many superstitions. A study of its ways of living provides sound training in common sense.)

The habits of a shore crab, hermit crab, etc.

The life of termites and ants.

The life of water lizards.

The habits of rice-field birds (or other common birds associated with Man), their distribution, food, etc.

(*b*) Studies of growth and factors which affect it, such as temperature and humidity. Locusts, stick-insects, snails or slugs, caterpillars, frog tadpoles, etc., may be used.

(*c*) Metamorphosis, hibernation, aestivation, migration. (Metamorphosis usually proves of interest to younger classes and is readily followed. Migration offers opportunity for joint studies with far-distant schools.)

(*d*) Osmo-regulation, cold-hardiness, adaptation to salt water. (These are laboratory topics which, because they call upon specialist knowledge in physics and chemistry, can only be undertaken by the more advanced pupils of the upper school.)

(*e*) Respiratory metabolism in relation to food, age and stage. (These topics also are open only to senior pupils. Though gravimetric techniques are desirable much may be done in volumetric terms. Reference is made to apparatus on page 192.)

(2) The physiology of organ systems. The study of the animal as a whole is followed by experimental work in the laboratory to explore the actions of separate organs and organ systems. A syllabus for sixth form (pre-university) pupils is shown briefly here. It should be noted, however, that some such work may be attempted by, or demonstrated to classes at the School Leaving Certificate stage.

(*a*) Nutrition.
  Tests to show the presence of carbon, hydrogen, nitrogen, phosphorus, sulphur, iron, and calcium in animal tissues and in food-stuffs.
  Tests for carbohydrates, fats, proteins.
  Simple experiments on the chemistry of carbohydrates, fats, proteins.
  Qualitative analysis of common food-stuffs.

(*b*) Digestion.
  The digestive action of saliva.
  Digestion of carbohydrates, fats, proteins; enzymes.
  Experiments on bile.

(*c*) The blood.
  Properties of blood and its histological structure.
  Clotting.
  The blood serum and blood cells.
  The respiratory pigments and their functions.
  Experiments on the vertebrate heart.
  Experiments on the invertebrate heart.

(*d*) Respiration.
  Mechanics of respiration in selected types.
  Analysis of inspired and expired air.
  Measurement of respiratory rates.
  Factors affecting respiratory rates.
  Anaerobic and aerobic respiration.

(*e*) Nerve muscle experiments.
  Electric stimulation of muscle.

Experiments on nerve muscle preparations.
Muscle physiology and histology.
Voluntary, involuntary and cardiac muscle.

(*f*) Sense-organs.
The cutaneous senses.
Taste and smell.
Hearing.
Experiments on vision.

(*g*) The physiology of reproduction.
The reproductive cells.
Fertilization.
Early segmentation.
Mechanics of embryonic growth and parturition.

These notes are far from complete, and each teacher must extend or modify them as needed for his own work. A common problem is that many teachers, having been trained mostly in morphology, anatomy and systematics, do not know how to conduct a sound course in physiology. Only in recent years has it become possible for such teachers to acquire a knowledge of physiology quickly. There have been no books of the appropriate kind, as existing texts have been too specialized and too advanced. However, the position is now improving, as may be seen from the bibliography. But there is still a dearth of books suitable for use by pupils; and those in existence mostly require modification or adaptation for use in any particular area.

Thus the teacher has to work out details of physiological work to meet his own needs. These may be prepared as 'work sheets' for class use. The material may be arranged under a series of headings, for example:

Purpose of experiment..............................
References to structures, etc. ....
Apparatus needed.....................................
Setting up the experiment ....
Conducting the experiment ....
Interpretation of results..............................

Plant physiology. Plant physiology has usually been given far more time in schools than animal physiology; but, despite this, it is often dealt with through reading rather than doing. Moreover, the relationship between laboratory experiment and the plant in the field does not always receive enough attention.

The general aims are the same as those in the teaching of animal physiology: to encourage an understanding of how the plant behaves and responds, and to show the relations between structure and function. Most of the suggestions already made about practical work apply to plant physiology. As a guide to what may be considered desirable for pre-university pupils, see Table VIII.

TABLE VIII

List of experiments in plant physiology for sixth form pupils

(A 'period' is assumed to be forty minutes)

Experiment	*Number of periods required*	
		Photosynthesis
1	2	Reducing sugars in a leaf extract and a leaf section
2	1	Non-reducing and combined sugars in leaf extract
3	2	The formation of starch from sugar
4	1	The taking up of carbon dioxide during starch formation
5	2	The formation of free oxygen
6	2	The necessity of light for photosynthesis
7	2	The extraction and spectroscopy of chlorophyll
8	2	The air-space system in a leaf
		Respiration
9	1	Liberation of heat during respiration
10	3	Loss of weight during respiration
11	2	Volumetric determination of the carbon dioxide produced at a constant temperature
12	2	Determination of the effect of rise of temperature on rate of carbon dioxide production
13	2	Demonstration and determination of respiratory quotient
14	2	Demonstration of anaerobic respiration
15	2	The formation of carbon dioxide from sugar by yeast
16	1	Presence of the respiratory enzyme, diastase

Experiment	*Number of periods required*	
		Plant nutrition
17	3	Water culture experiments
18	1	Tests for proteins
19		Tests for fats
20		Tests for ligno-cellulose
21	1	Presence of protein in plants
22		Presence of fats as storage form
23		Presence of starch as storage form
24	1	The disappearance of starch from darkened leaves
25	2	The significance of leguminous root nodules
		Water relations
26	2	Localization of water loss
27	1	Comparison of stomatal frequency
28	3	Transpiration rate under varying conditions
29	1	Demonstration of leaf suction
30	1	Demonstration of root pressure
31	1	Demonstration of suction pressure
32	1	Demonstration of path of water conduction
33	1	Water in relation to formation of root hairs
34	2	Artificially produced zerophytism
35	3	Osmotic pressure in mesophytes, zerophytes, hydrophytes and parasites
		Growth
36	2	Auxanometer studies of growth rate
37	4	Grand period of growth studied in sunflower
38	2	Increase of dry weight during growth
39	2	Location of growth region in bean radicle
		Germination
40	2	Conditions required for germination
41	1	Metabolic changes during germination
		Response to stimuli
42	1	Directional response to light
43	1	Photoperiodism
44	1	Etiolation
45	1	Measurement of light intensity
46	1	Geotropism
47	1	Region of response to gravity and light
48	1	Hydrotropism
49	1	Response to two simultaneous stimuli
50	1	Haptotropism

Total: 75 periods. (25 additional periods are required for extension or repetition of experiments)

The times allowed in this table are only a guide and may have to be modified. Nearly every experiment demands some quantitative work and usually the apparatus has to be set up in one period and used in the next. The estimates given here do not show the actual disposition of the time required for the experiment.

Physiological experiments, whether in zoology or botany, offer opportunity for both qualitative and quantitative work. In the case of the latter, results should be pooled, the mean values calculated and the significance of the variations discussed. There should be a clear and careful distinction between systematic errors (due to the apparatus or the procedure), errors due to the personal factor, and variations due to real differences in natural processes and functions. In other words, the study of physiology offers an opportunity to discuss the applications of scientific method to specific situations.

A defence often put forward by those who devote little time to physiological work is that it demands apparatus which is often unavailable because of its high cost. This can be overcome to some extent by making up apparatus in the laboratory, with the aid of hand-work classes and the workshop. Designs for certain pieces of apparatus are given in Chapter VII and references to other sources of information are listed in the bibliography. The making of apparatus, with the help of pupils, not only overcomes a teaching problem, but contributes to skill, to the development of confidence and satisfaction, and to the growth of new attitudes to the manual worker, whose status and prestige in many countries is far too low.

The teaching of ecology

Some knowledge of ecology is essential for a proper understanding of biological principles, and as an introduction to certain aspects of social biology, besides being demanded in most examinations. Unfortunately ecology in school often suffers from three faults:

1. It is usually taught as a theory which lacks a sufficient basis of field-work and experiment.

2. It tends to be primarily a study of the systematics (taxonomics) of distribution and, though attention is given to morphological specialization, the physiological foundations of this are not pursued by experimental means.
3. It is frequently a study of details instead of principles, because the requirement is so often 'for a knowledge of the ecology of a sandy foreshore' (or a paddy field, or some other specific location).

In an effort to remedy these faults, various proposals are made here, but only briefly and in broad terms. It is the responsibility of each teacher to adapt and amplify them to meet local conditions. It should also be noted that ecological studies provide excellent opportunities for four very desirable objectives:

1. Demonstration of the link between the animal and plant worlds and their interdependence.
2. Demonstration of the link between the 'pure' science of the laboratory and the 'applied' science of the garden and countryside.
3. Emphasis on the value of long-term studies and projects carried on from year to year, when broad trends begin to emerge from what otherwise may appear to be occasional, irregular or passing phenomena.
4. To provide a central theme for the work of a school natural history society.

Ecology may not appear as such in the syllabus until late in school life, but it should be inherent in all biological work from the very beginning. Unless there is a clear aim, the concept of biology as a subject concerned with the interactions of organisms and environments, there can never be a real understanding of living relationships.

The difficulties of ecological study must not be underrated, but most, if not all of them, can be overcome with patience and ingenuity.

In many tropical regions there often appears to be a lack of variety. The country may seem to extend, mile after mile, with a uniform and monotonous sameness of fauna and flora. This appearance is deceptive, because it is true only in broad terms.

An examination of small areas, lesser habitats and micro-climates usually discloses wealth of variety. Every house offers a habitat which varies from its surrounding area: for example, the gecko and cockroach are typical of domestic fauna, just as are some of the moulds and lichens. The rain-water butt, the village well and the temporary puddle are different from each other, and from the more permanent water of river, lake, village tank or town reservoir. Thatched roofs, of coconut leaves, grass or rushes offer a specialized habitat. The common division of the year into wet and dry periods offers ecological opportunity. And even the various domestic animals, goat, dog, cat, cow, horse and elephant, have specialized ectoparasitic fauna.

Those who teach in town schools frequently believe that they have less opportunity for ecological study than those in rural schools. Yet this is not always the case in tropical countries. The cities are often little industrialized, so that many elements of rural life still exist in the urban conditions. However, there are some difficulties in the towns, but most of them can be overcome. Some of the potential habitats have already been mentioned. To these may be added park spaces, playing-fields, and the school grounds and garden.

In addition, it is often possible to provide artificial opportunity for ecological work in the school garden. Before discussing how this may be done let us consider the kinds of work and some of the facilities needed.

Class-room work in ecology. Although ecology is a field-study, preparation for it is made in the class-room. Thus it is necessary to have available a supply of suitable illustrative material, which should be built up by continued study of local environments. Such material is most convenient in the form of film-strips or slides. A typical set, for example, may include:

1. Map or maps of area showing topography, climatic conditions and distribution of flora and fauna.
2. Photographic records of typical habitats showing seasonal variations.
3. Diagrammatic transects, profiles and other such charts.

4. Tabulated data.
5. Suitable reading material.

Laboratory work. Ecological work in the laboratory has two phases, that preparatory to and that subsequent to field-work. The preparatory work is mostly concerned with:

(*a*) Learning to recognize and identify flora and fauna from different habitats.

(*b*) Studying the morphological and physiological specializations related to ecological distribution.

(*c*) Conducting simple laboratory experiments on artificially induced responses to varying conditions.

(*d*) Learning to use apparatus and procedures related to ecology, for example: mechanical analysis of soil;
chemical analysis of soil;
estimation of soil water content;
estimation of soil pH;
atmometry, measurement of evaporation capacity, etc.;
measurement of light.

The work subsequent to that in the field consists of the analysis of materials and data brought back to the laboratory after an expedition.

Field-work. Class-room and laboratory knowledge must also be applied to actual conditions and problems in the field. The organization of field-work is greatly dependent upon local conditions and opportunities, but experience suggests that it should include more than the minimal study laid down in most syllabuses.

A convenient scheme of organization includes the following:

(*a*) The study, by all pupils, of two or three appropriate habitats, through visits paid at different times to note seasonal variations. Whenever possible the habitats should be on, or near the school grounds.

(*b*) Continuous all-year-round study, of one or two selected sites, by a few pupils with a special interest in ecology; or similar study confined to the ecology of a single species of animal or plant. Such studies should be carried on from year to year, and all records should be carefully filed so that, over a period of time, a comprehensive study is built up. In some countries there are schools in which this kind of work has produced results of considerable scientific interest and importance. Moreover it is not only the big and well-known schools which have done work of this kind.* Thus, such experience is not only of value in the formal and informal education of the pupil, but may be a contribution to scientific knowledge. It is of equal, or greater value in tropical countries, where there is even more need for survey work, and where the importance of contact between the scientist and the pupil, and between pupil and real problems in science, is often less widely appreciated.

(*c*) Project studies undertaken by individuals, or small groups of pupils, in their free time and during holidays. This kind of work is usually organized under the sponsorship of the school natural history society. A project, small enough to be feasible, providing frequent and common opportunity, and with considerable interest and scientific value, may be, for instance, the study of a newly cleaned out ditch, or a newly cleared site, in relation to ecological succession.

Plants being more static than animals, their ecology is less difficult to study, and so receives more attention and tends to be further developed. It is possible, however, to give attention to the fauna as well as the flora. In many areas little is known about the local animal ecology; but this provides a challenge, an incentive to effort, because any information obtained may prove to be a new contribution to knowledge. Examples of topics suitable for consideration are:

1. Local fauna records, for example, of moths, butterflies, birds, etc.
2. Micro-faunal studies of a restricted habitat such as a well or pond, or a pitcher-plant cup.
3. Adaptation of different types to a specific environment, such

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* Much of the field survey for the Land Utilization Map of England was done by children in primary (elementary) schools.

as the variations in colour of an animal species found in different places.

4. Adaptation in related species living under different conditions: for example, aquatic insects in still and running water.

5. Animal associations under marginal conditions, such as the edge of a pond.

6. Animal associations at different times: for example, day and night; wet and dry seasons.

It must also be remembered that animals and plants live in close association with each other, not only in terms of symbiosis or parasitism but in other ways, which, though apparently free, are functionally obligatory. Examples should be found and studied: for instance, in 'food chains' or in cases where certain animals are restricted to areas in which a particular vegetation offers cover.

Simulated habitats. The experience of many teachers over many years shows that certain types of ecological habitat can be set up artificially. The advantages of such a habitat are obvious: a long, close, continued and detailed study is made possible and easy. Yet little has been attempted in tropical countries, except by one or two horticultural firms and in a few public parks. The fact that it *has* been done means, however, that some experience and information are available, to be turned to account in schools.

The setting up of artificial ecological habitats needs:

(*a*) An understanding of the operative climatic factors and their range and variation in the vicinity.

(*b*) An understanding of the response behaviour of the flora (and fauna) under conditions which cannot, except in rare cases, be exact copies of the natural habitat.

(*c*) An understanding of the limitations of the methods to be employed in relation to local conditions. For example, it is far easier to simulate a sub-tropical climate in a temperate zone garden than vice versa.

(*d*) A determination of the conditions to be simulated, and the degree of tolerance, beyond which response may be abnormal.

(*e*) An investigation to make sure that local materials and resources are sufficient for the attempt, and that interest and effort will be sustained over a sufficient period.

(*f*) An assurance that the sites will be protected and cared for continuously, and not merely during the school term. (Once pupils are interested and begin to understand the value of such work, it is almost certain they will be ready to give constant service to such projects.)

(*g*) The certainty that pupils really understand the value of such work in relation to their curriculum.

Habitats chosen for simulation should be those least like the local environment. In the tropics, however, unless the school is at a considerable altitude, it is useless to attempt to simulate conditions beyond the sub-tropical. Therefore the work should be centred on variations from the local mean. The choice depends upon:

(*a*) Selection of suitable plants, hardy enough to withstand 'domestication' and which exhibit an obvious specialization.

(*b*) Control in terms of soil, drainage and, to a lesser extent, insolation, which may be varied by screens or trees (to reduce light-intensity and surface temperatures).

The very considerable range of floral variation in different parts of the tropics makes it impossible to give lists of suitable species. Even proposals for artificial habitats are likely to be of restricted use, but those mentioned here may be capable of adaptation.

1. *Xerophytic habitats*. A low water content, and an open aspect giving exposure to sun and wind, are the main factors in xerophytic situations. Three methods may be tried to simulate such conditions. In each case the structure should be placed in an open unsheltered spot.

(*a*) *Dry walling*. A wall is built of flat stones placed one on the other with very little earth between the stone layers. A thicker layer of earth, about one inch deep, may be put on top of the wall and kept in place by a row of small stones along each edge of the top. The specimens are planted in crevices in the sides of the wall and on the top. Mosses and lichens may be used as a foundation and are also useful in 'binding' the structure together.

It is often possible to collect from a crumbling wall, rock pieces which already carry a xerophytic flora and transport them to a new position.

A typical animal fauna, millipedes, centipedes, wood-lice, etc., usually takes up residence fairly quickly in such a suitable habitat.

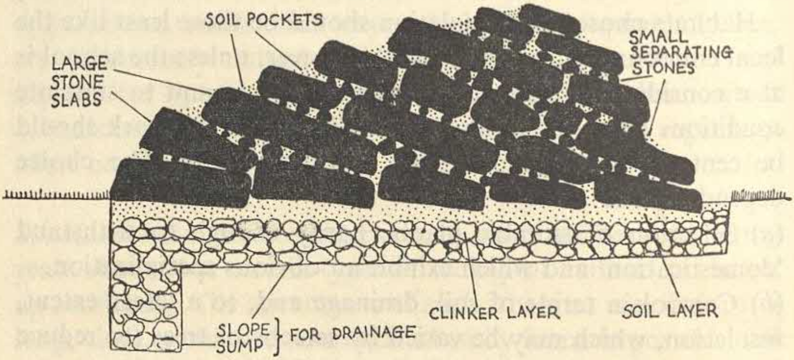

FIGURE 3.—A section through a rockery

(*b*) *Rockery*. A rockery is similar to a dry wall but has a greater relative amount of soil. It should be well drained below. Below the rockery is a pit with the floor sloping to a deeper sump. Both are nearly filled with clinker or large stones on which lies an earth layer. On this the rockery is built of large flat slabs which are tilted. They are separated by small stones and earth. (See Fig. 3.)

(*c*) *Scree*. Scree structure is found at cliff bases as a result of weathering. It may be simulated by building a rockery with a strong retaining wall. Between this and the face of the rockery are two layers of stone, very fine above and coarser below. (See Fig. 4.)

2. *Aquatic habitats*. Aquatic habitats vary, through swamp and marsh, from permanent water to dry land. Although it is

possible to reproduce all these conditions along a continuous transect, it is often more convenient to arrange each separately.

(*a*) *Sunken tubs*. A wooden barrel may be sawn round the middle. Each half may be sunk, flush with the ground surface, to provide a small pond. In malarial areas the 'pond' must be dusted with DDT or covered by a thin oil film. This is unavoidable, in the interest of health, but it cuts out much insect life.

(*b*) *Ponds*. These are dug out and 'puddled' with clay or, if possible, lined with concrete. There should be a clinker layer under some part of the pond with a drain plug just above it. If it is proposed to rear frogs and toads, at least one side of the pond must slope gently to ground level so that the animals can enter and leave the water easily. A layer of mud must be present for rooted plants and for such fauna as the burrowing Mollusca, worms, etc.

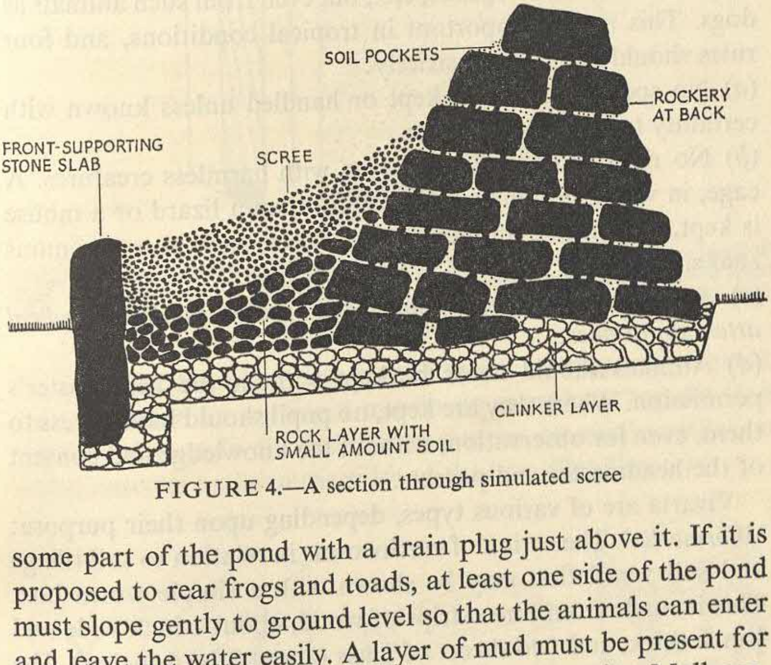
SOIL POCKETS
ROCKERY AT BACK
FRONT-SUPPORTING STONE SLAB
SCREE
CLINKER LAYER
ROCK LAYER WITH SMALL AMOUNT SOIL

FIGURE 4.—A section through simulated scree

It is sometimes found convenient to divide a pond into sections, either by vertical brick or concrete walls, or by fine-mesh wire netting, in order to keep certain species apart. Unfortunately this often looks like an attempt to rear particular species in isolation, rather than to reconstruct an ecological situation.

3. *Vivaria.* It is desirable to keep a certain number of animals in captivity in order that their lives and habitats may be studied. But they must be kept in conditions offering a considerable degree of freedom as well as simulating nature; otherwise they are unhappy and abnormal, and probably do not survive. Some species should be kept for only short periods and then released. Moreover, it should not be forgotten that many animals may be watched under natural conditions.

At all times the element of danger must be remembered: not only from snakes, scorpions, etc., but even from such animals as dogs. This is very important in tropical conditions, and four rules should be followed strictly:

(*a*) No species should be kept or handled unless known with certainty to be quite harmless.

(*b*) No risks should be taken even with harmless creatures. A cage, in which nothing more harmful than a lizard or a mouse is kept, may attract an unwelcome visitor, such as a venomous snake.

(*c*) *Any* injury from *any* animal should receive *qualified medical attention at once.*

(*d*) Animals should never be kept without the headmaster's permission. Where they are kept, no pupil should have access to them, even for observation, without the knowledge and consent of the headmaster and parents.

Vivaria are of various types, depending upon their purpose:

'*Wormeries*'. The action of earthworms in relation to soil tillage and soil ventilation may be shown with a simple worm box. This is made from three strips of wood, about 1 inch wide and ½ inch thick, and two sheets of glass (about 8 by 6 inches). The wood forms a frame for the glass sides, to produce a tall narrow box (Fig. 5). About an inch of dark soil is put in the bottom, and then two or three medium-sized worms. These are covered by an inch of light-coloured, sandy soil. Alternate layers of dark and light soil are then used to fill the box. The movements of the worms mix up the soil layers, and their 'burrows', in places against the glass and so easily visible, allow ventilation of the lower soil layers.

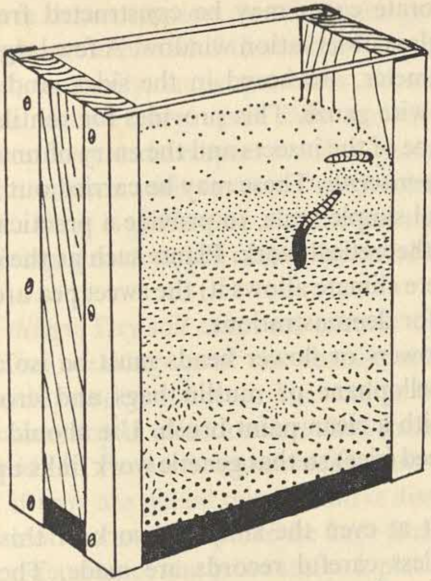

FIGURE 5.—A 'wormery'. The box consists of two wooden strips and a wooden base (shown in black). The glass sides are held in place by angle strips. It is filled with layers of earth of different colours which become mingled at the edges by the burrowing of the worms

Insect cages. Simple cages, usually to act as temporary homes, may be made by putting a muslin or cellophane top on to a cardboard box. In the latter case a series of small ventilation holes must be made in the sides of the box. (See Fig. 6.)

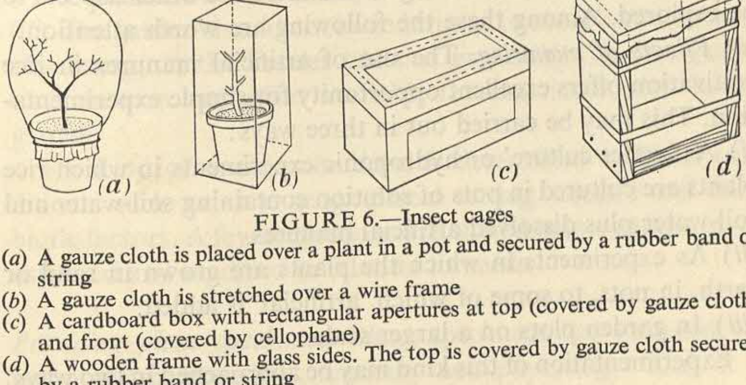

FIGURE 6.—Insect cages

(*a*) A gauze cloth is placed over a plant in a pot and secured by a rubber band or string
(*b*) A gauze cloth is stretched over a wire frame
(*c*) A cardboard box with rectangular apertures at top (covered by gauze cloth) and front (covered by cellophane)
(*d*) A wooden frame with glass sides. The top is covered by gauze cloth secured by a rubber band or string

More elaborate cages may be constructed from wood and fitted with a glass observation window. A few large holes, about 1 inch in diameter, are bored in the sides, and the apertures covered with wire gauze. This provides for ventilation but prevents the escape of the insects and the entry of unwanted guests.

Mendelian experiments. These may be carried out in the garden, on a small and simple scale, to provide a practical background for the more theoretical work. Plants such as the evening primrose and (where climate allows it) the sweet pea are easily grown and suitable for demonstrations.

Separate flowers or flower heads must be isolated and protected with cellophane or muslin bags and cross-pollination carried out with a clean paint brush. Use should also be made of pure line seed (rice) so that genetic work links up with applied biology.

No attempt at even the simplest work of this kind can be successful unless careful records are made. These should be preserved from year to year so that a considerable body of data may be built up. Mendelian relations are more likely to appear than when data are collected over one year only.

'*Cropping*' *or yield experiments*. In the interests of social progress the resources of the school garden should be connected with the problems of rural living. It is therefore important to use the garden in relation to the teaching of agriculture and rural science. In addition to genetics there are other aspects to be explored. Among these the following are worth attention:

(*a*) *Effects of manuring*. The use of artificial manures in rice cultivation offers excellent opportunity for simple experimentation. This may be carried out in three ways:

(*i*) As 'water culture' or hydroponic experiments in which rice plants are cultured in pots of solution containing soil-water and soil-water plus dissolved artificial manures.

(*ii*) As experiments in which the plants are grown in sand or earth, in pots, to some of which 'artificial' is added.

(*iii*) In garden plots on a larger scale.

Experimentation of this kind may be approached in two ways:

firstly as a pure demonstration, in which the potential results are declared and are achieved if the teacher has all the variants under control; secondly, as a problem situation in which the results are known only when they are obtained. When lack of space prevents development of a garden it may be simpler to demonstrate with water or sand cultures. Where a garden is available it is preferable to treat the task in problem terms, thus giving greater opportunity for training in scientific methods.

(*b*) *Effects of tillage*. Dry soil crops are affected by the tillage of the ground. The breaking-up of the surface soil affects temperature, humidity and ventilation. This can be investigated by growing the same crop in tilled and un-tilled ground, and comparing the yield. In the latter case weeds must be cut off at ground level; if they are pulled out the soil is disturbed.

The purpose of the garden should be kept firmly in mind: it should be an extension of the laboratory, a place in which the ideas learned in the laboratory can be put to a field test. It is only indirectly a source of either vegetables or floral decorations. The biology garden should be used particularly as a place in which to demonstrate the relations between biological theory and agricultural fact, so that it may contribute to a greater understanding of biology in connection with social needs and everyday life.

It should be remembered that:

(*i*) A garden, however small, is better than none.

(*ii*) The garden should not be so large as to absorb all the available energy in the heavier tasks of gardening. There must be time, interest and effort available for experimentation in the garden.

The kind of work to be done is determined by local conditions, such as area, geographical setting, climate and local biotic factors. A few suggestions are offered below which can be extended and modified in relation to needs.

Providing plant specimens. Plant specimens are required for taxonomy (systematics), anatomy and physiology. Thus it is wise to decide upon the species most suited to the needs of these branches of study and then to build up garden stocks. Where they are required in considerable numbers, such specimens may be grown in formal beds, but too strong an emphasis upon 'systematic' beds tends to artificiality, because ecological relationships are ignored. A compromise is usually possible, and in any case such methods as those already suggested for simulating ecological habitats should also be applied in the garden.

Hedges should be grown and ornamental shrubs planted. If space permits, a shrubbery, or even a small copse or woodland patch, may be developed. It is also desirable to have places for growing vegetables and fruits, not primarily for food, but to demonstrate selected varieties and procedures.

In addition to these generalized purposes, the garden should be used for special cases. For example:

Life forms. Suitable species to show the structure of rhizomes, aerial roots, varieties of rooting systems, etc.

Climbing plants. A series to show various methods of climbing. (Arrangements should be made to demonstrate the effect of the angle of support, limiting diameter of the support, etc. Open-air experiments may be made on reaction times of the response of tendrils to stimulation, location of response areas, etc.)

Floral mechanisms, post-floral mechanisms, pollination, etc. (Each teacher should select and grow specimens suitable for various demonstrations.)

Insect–flower relationships. (These offer much of interest, especially with regard to morphological features, for example long proboscides related to long corolla tubes; colour reactions, etc. Here also selection must be made on a local basis.)

Animal cages. The size and type of the cage must obviously be related to the size and type of animal, and only a few general hints are given here. (See Fig. 7.)

Wood is the most convenient constructional material as it is easily worked. Plywood, though apparently convenient, is un-

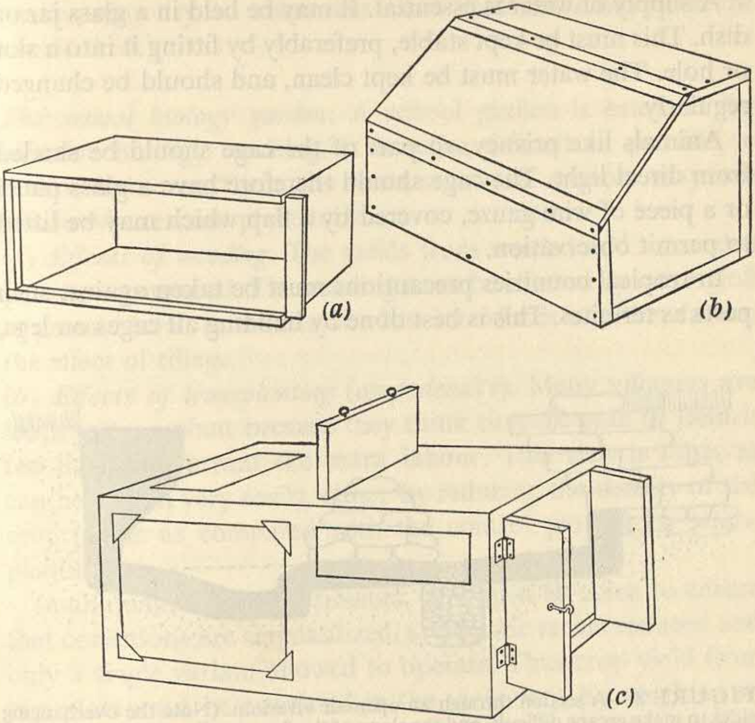

FIGURE 7.—Animal cages

(*a*) The sliding cover of a wooden chalk-box is replaced by glass
(*b*) One long edge of a wooden box is removed, leaving the shape shown. A sheet of glass slides under metal strips to close the opening
(*c*) A large wooden cage with doors. There is a sliding partition in the middle. There is a glass window on the left. The ventilation apertures are closed by metal gauze

suitable, unless resin-bonded, when, though waterproof, it is expensive.

In the interests of hygiene, a false floor which can be withdrawn for cleaning, should be fitted. To facilitate cleaning it is useful to divide the cage into two parts with a communicating aperture, which is closed by a shutter operated from outside by a rod or lever. The inmates may then be kept in one part while the other is cleaned.

Efficient ventilation must be provided by apertures cut in the walls and covered by wire gauze to prevent escape.

A supply of water is essential. It may be held in a glass jar or dish. This must be kept stable, preferably by fitting it into a slot or hole. The water must be kept clean, and should be changed regularly.

Animals like privacy, so part of the cage should be shaded from direct light. The cage should therefore have a glass panel or a piece of wire gauze, covered by a flap which may be lifted to permit observation.

In tropical countries precautions must be taken against such pests as termites. This is best done by building all cages on legs, the feet of which stand in pots containing water and an insecticide (e.g. DDT).

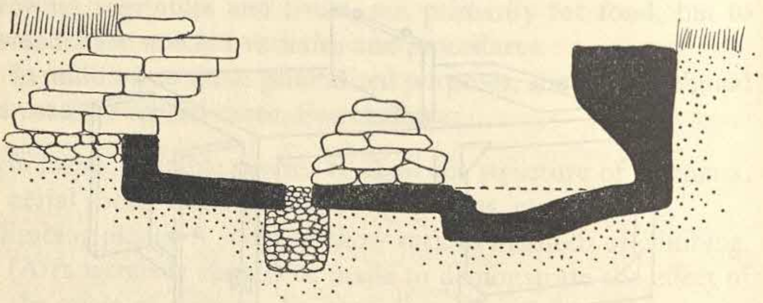

FIGURE 8.—A section through an open-air vivarium. (Note the overhanging sides to make escape difficult, and the slope of the floor to allow easy entry to and exit from the water)

All cages should be protected from direct sunlight, and the doors should have strong hinges and efficient but simple latches.

An outdoor vivarium. It is frequently useful to have an outdoor vivarium in which small animals may live as closely as possible to their natural state. Essentially this consists of a shallow pit with sides sloping *inwards* at a fairly steep angle so that escape is rendered difficult. The centre may be filled with a rockery to provide shelter. There should be a water supply, not only for drinking, but for living in. A design is shown in Fig. 8.

Frogs, toads, newts, wall-lizards and non-poisonous snakes may be kept in this way. (*N.B.* The possibility that venomous snakes may try to share the same quarters must never be overlooked.)

The school biology garden. A school garden is essential for effective biology teaching. It may be difficult to provide in towns, but even there the most restricted schools may use window-boxes and plant-tubs.

(*a*) *Effects of weeding*. The yields from weeded and unweeded plots are compared. The weeding must be effected by cutting off at ground level, as the use of a hoe introduces a further factor, the effect of tillage.

(*b*) *Effects of transplanting* (*crop density*). Many villagers are loath to transplant because they think that the gain in yield is too little to warrant the extra labour. This view is false, as can be shown very easily, either by reducing the density of the crop plants as compared with the control plot, or by transplanting.

In all quantitative experiments, care must be taken to ensure that conditions are standardized, systematic errors reduced and only a single variant allowed to operate. Thus crop yield from two plots must be estimated in the same way, by weighing or counting. Moreover, the use of only two plots, one the 'experiment' and the other the 'control', is likely to be unreliable, so it is usual to use several plots. The problems of planning experiments of this kind have received a great deal of attention from the statistician and it is now usual to plan in terms of 'randomized blocks' or by the 'Latin square' method.

The random block method may be illustrated by an experiment to determine the relative value of three kinds of fertilizer as a source of nitrogen. A control with no added nitrogen is needed. The plots may be arranged as shown on next page, or in any other random manner. Each block contains plots for all the treatments (including the control), and there are as many blocks as there are treatments.

In the Latin square there are as many repetitions as there are treatments. This method was used by a school which participated in an experiment to compare the value of nitrogen and

Randomized block

C	S	O	M
O	M	C	S
S	O	S	O
C	M	M	C

C—cyanamide of calcium
M—muriate of potash
S—sulphate of ammonia
O—control, no added nitrogen

phosphoric acid applied in organic form or as an inorganic salt. Sixteen plots were used and arranged as shown below.

Experimentation of this kind should not be allowed to become so complex that it is too difficult for pupils to understand. It should be undertaken with three clear aims:

(*i*) To help the understanding of biological ideas.
(*ii*) To encourage the understanding of scientific method.
(*iii*) To produce a more scientific attitude towards agriculture.

None of these aims can be attained unless the pupil understands the whole process: problem, procedure and products.

Latin square

B	A	C	D
D	B	A	C
A	C	D	B
C	D	B	A

A—Dried blood and bone flour
C—Sulphate of ammonia and superphosphate
B—Dried blood and superphosphate
D—Sulphate of ammonia and bone flour

Thus the technique and its implications must be discussed fully and the results considered from every angle.

In a tropical setting, as elsewhere, the details vary with local conditions. A more suitable crop must be used, for example, rice, maize, cassava (manioc). The help of the local agricultural department should be sought, and the advisory officer should be invited to the school to talk about his work. It may not be possible to conduct such experiments on a large scale, but even when limited to a series of flower-pots they are most valuable.

Sylviculture. Although many metal alloys are available and there is a rapidly increasing range of plastics, timber remains an extremely important material for many purposes. In many countries, for example, it is an important item in external economy, but everywhere it is of internal importance for fuel or construction. Commercial demands for timber, local fuel consumption and other factors, are endangering reserves in many areas. Thus afforestation in the interests of renewal, as soil protection against erosion, is important. Forestry Departments are engaged in important work in the task of preserving, replacing and extending timber supplies in tropical areas.

In many places there is needless waste of timber through clearing of forest land by fire for short-term cultivation by semi-nomadic peoples. Continuation of this system of cultivation depends upon many factors and cannot be altered easily or quickly. Nevertheless, informed opinion among educated people may accelerate efforts to find alternatives. Biological education should contribute to the building up of this informal opinion.

It is not suggested that 'forestry' should be included in the school syllabus, but that interest should be fostered by the teacher's attitude and through non-curricular activities. Sylviculture may also be encouraged in other ways. For example, the school natural history society may collect specimens of local trees in various ways:

(*a*) Drawings, paintings and photographs, to show the general form and appearance of the tree as a whole.

(*b*) Similar illustrations of bark, leaves, flowers and fruits.

(*c*) Specimens of bark, leaves, flowers and fruits.

(*d*) Specimens of the timber cut in different ways, e.g. transverse, quarter sawn, rift sawn, etc.

(*e*) Information concerning distribution and economic uses.

Experimental work may be carried out in the school garden:

(*i*) The germination of seeds in seed beds which may be as small as 2 feet by 1 foot, allowing a number of species to be grown.

(*ii*) Transplanting of saplings to larger nursery beds, and culturing until they reach a height of 4 to 6 feet.

(*iii*) Planting out the young trees, and providing a shade cover, ornamented border, or small copse, in the school grounds.

(*iv*) Artificial propagation by:

Layering. A branch is bent down to the soil, and cut or notched on its lower surface, then covered with soil and held down by a peg. When the 'layer' has set (i.e. produced adventitious roots), its shoot grows rapidly. It should be supported by a stake, and eventually cut free of the parent plant and then transplanted. (See Fig. 9 (*a*).)

(The natural form of layering is by suckers and stolons. The former are subsidiary shoots arising from the roots on stock [bole]. The latter are pendent shoots which take root on reaching the ground, as in the case of the banyan tree.) Layering is useful for species not easily grown from seed or cuttings, such as *Liriodendron*, or *Magnolia*.

Cuttings. Small healthy shoots are cut off the main plant and embedded in the soil to encourage the formation of adventitious roots. The soil for setting cuttings should be fine, with a good humus content. The cutting should be protected from extremes of weather. (See Fig. 9 (*b*).)

Grafting. A piece of one bush or tree is cut off and inserted into a slit in another, where it 'sets' by combial activity. There are two partners in a graft, the stock and the scion, the former being recipient of the latter. Grafting allows maximum growth in minimum time, especially as several scions may be inserted on a single stock. Two simple forms of grafting are shown in Figs. 9 (*d*) (*i*), (*ii*).

Budding. This is a special form of grafting, in which a single

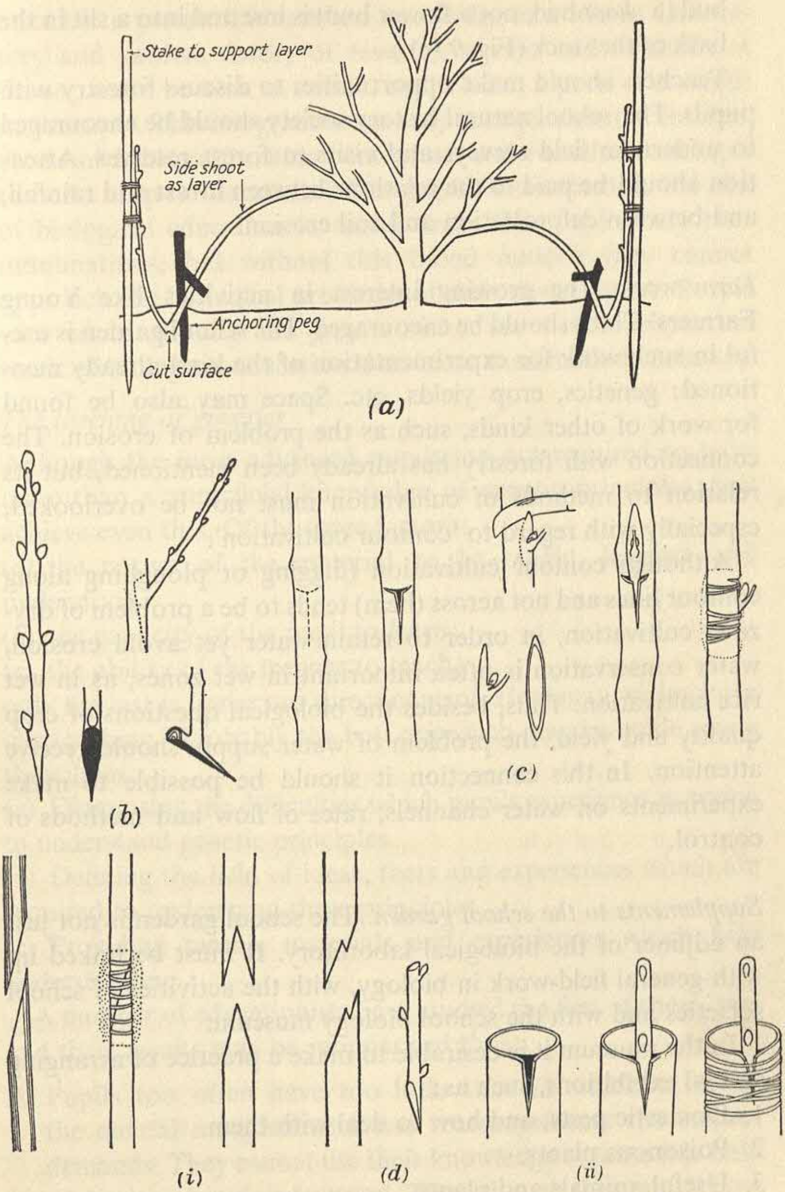

FIGURE 9.—Some methods of artificial propagation

(a) Layering
(b) Cutting
(c) Budding
(d) Grafting

bud (a *shoot* bud, not a flower bud) is inserted into a slit in the bark of the stock (Fig. 9 (*c*).).

Teachers should make opportunities to discuss forestry with pupils. The school natural history society should be encouraged to undertake field surveys and visits to forest reserves. Attention should be paid to the relations between forest and rainfall, and between deforestation and soil erosion.

Farm work. The growing interest in activities like Young Farmers' Clubs should be encouraged. The school garden is useful in such work for experimentation of the kind already mentioned: genetics, crop yields, etc. Space may also be found for work of other kinds, such as the problem of erosion. The connection with forestry has already been mentioned, but its relation to methods of cultivation must not be overlooked, especially with regard to 'contour cultivation'.

Although contour cultivation (digging or ploughing along contour lines and not across them) tends to be a problem of dry-zone cultivation, in order to retain water yet avoid erosion, water conservation is often important in wet zones, as in wet rice cultivation. Thus, besides the biological questions of crop quality and yield, the problem of water supply should receive attention. In this connection it should be possible to make experiments on water channels, rates of flow and methods of control.

Supplements to the school garden. The school garden is not just an adjunct of the biological laboratory. It must be linked up with general field-work in biology, with the activities of school societies and with the school biology museum.

In the museum it is desirable to make a practice of arranging special exhibitions, such as:

1. Domestic pests, and how to deal with them.
2. Poisonous plants.
3. Useful animals and plants.
4. Modern methods of growing a particular local crop.

In this work, as in all aspects of biological education, the aim must be to present the relevant knowledge as a whole. Laboratory and garden, theory of research worker and methods of farmer, must be seen as minor, but related, aspects of a single major topic. This integration can only emerge when the teacher, aware of it himself, makes continuous and conscious attempts to build it up in the minds of his pupils. His success is the aim of biological education in social terms. His pupils may pass examinations, but without this broad outlook they cannot approach the biological problems of their environment. People with wiser attitudes and greater vision are a more important result of biological education than mere examination successes.

The teaching of genetics

Although the most advanced pupils are not required to have more than a superficial knowledge of genetic principles, few achieve even this. Of the three factors:

(*a*) the nature of the material to be taught, learned and understood;

(*b*) the capacity of the pupil to learn;

(*c*) the ability of the teacher to teach;

only the last is under our direct control. How may we improve our teaching? Probably the best approach may be made along three lines:

(*a*) Diagnosing the difficulties which pupils experience in trying to understand genetic principles.

(*b*) Defining the field of ideas, facts and experiences which are required to understand these principles.

(*c*) Providing means, materials and experiences which help understanding.

A number of educationists have studied the first of these lines and their results may be summarized thus:

A. Pupils too often have too little time in which to make the mental readjustments and rearrangements the subject demands. They cannot use their knowledge because it is only remembered, not understood. Thus, though they may 'know about' certain Mendelian patterns, they are unable to solve numerical examples on inheritance problems.

B. Pupils have insufficient practical experience. They have read of and talked about chromosomes, for example, but have never seen them, either in reality or as models.

C. Pupils lack appreciation of the different kinds of knowledge and of their relationships, which must be called upon as a basis for understanding genetic principles.

Each teacher should first decide how far this analysis is relevant in the case of his own pupils, and take steps to put things right. It is then necessary to determine the range of information and ideas to be covered, in order to use the third line of approach. It appears that the following are required, as basic knowledge and ideas for understanding genetics:

(*a*) The cell; its structure and inclusions, with some idea of their functions, and also of the distinction between what is known and what is surmised.

(*b*) The chromosomes; the changes which they undergo in mitotic and meiotic division.

(*c*) The idea of the gene and its relation to the chromosome.

(*d*) The significance of variations in characteristics between specimens of the same species.

(*e*) The simpler laws of heredity.

(*f*) The relation between cytological phenomena and the results of breeding.

(*g*) Elementary notions of statistical ideas such as the frequency curve of distribution, significant differences, etc. (Unless these are considered, pupils tend to expect every cross to result in a true Mendelian proportion.)

(*h*) Some reference to the history of theories of heredity. (This is worthwhile as an indication of how scientific theory is connected with the social and general ideas of the particular period.)

(*i*) Introductory ideas about the application of genetic knowledge to animal and plant breeding, with brief reference to human inheritance and social affairs.

Our third line of approach means that we should make possible experiences such as these:

(*a*) Microscopic examination of material stained to show the cytological structure of the cell: nucleus, nucleolus, inclusions, etc.

(*b*) Examination of specially prepared slides showing the chromosomes and the phenomena of mitosis and meiosis.

(*c*) Examination of models, charts, film-strips and films showing in reality, and as models and symbols, the nuclear phenomena.

(*d*) Simple breeding experiments with maize plants, the banana fly or other suitable material.

(*e*) Having access to numerical data which demonstrate the various Mendelian relationships, for example, figures accumulated over several years by successive biology classes.

(*f*) Practice in solving numerical examples.

The teacher who provides opportunity for such experiences finds that pupils' difficulties are greatly reduced. It is, of course, essential that the pupil should spread his work over a sufficient period of time to make the process of maturation possible.

No chance should be missed of discussing cell structure. Many pupils have no three-dimensional concept of the cell because they seldom see it, except as a plane figure in a textbook diagram. Whenever tissues are examined, if only in terms of gross anatomy, there is opportunity to learn about the cell. In addition, use should be made of models, modelling by the class, of stereograms, differential focussing and the like. There is a common, but unfortunate, belief that only the thinnest of microtome sections may be used for cytological study. In fact, thick sections, examined by differential focussing, often provide a better demonstration of nuclear phenomena. Plane after plane is brought into focus, and a diagram or model may be built up to record the observations, helping the pupil to realize that the cell is a three-dimensional structure. Indeed pupils should always be expected to show this feature in their drawings, and they should be expected, and helped, to make stereogrammatic diagrams showing cell structure.

Models may be made in clay, plasticine or wax (even coloured candle fat may be used) to show chromosome behaviour. The genes may be simulated with coloured wooden beads threaded on a string. If press-studs are driven into the wooden beads in polar positions, it is easily possible to alter the structure of the model, and so to demonstrate the phenomena of linkage, cross-over and so on.

Vital stains used with living materials, such as the growing tips and reproductive tissues of plants, are valuable aids in demonstrating cell structure.

A freezing microtome is a highly desirable piece of apparatus for the study of the cell, though it is seldom used often enough.

Another very useful technique is that known as dark-ground illumination. This is a method in which the object examined is illuminated from the periphery or rim of the field, the central rays being stopped by a disc. Special condensers are made for dark-ground illumination, but the effect may be produced by sticking a disc of opaque paper in the middle of the lowest optical surface of the condenser. (A certain amount of trial and error is needed to achieve a good result.)

Genetic knowledge has a direct application to agriculture, which is under Man's control. This should be emphasized and made a part of the work in the school garden. The department of agriculture in a particular area may be called on for help. Visits may be paid to experimental farms. Use should be made of agriculture bulletins and annual administration reports, etc. The teacher should find out what is available and guide his pupils in its uses, remembering that his selections should aid understanding without clogging memory. 'Understanding' must have two meanings: the formal sense of increased factual knowledge and the wider sense of new attitudes and increased appreciation of the significance of genetics. This significance should not be a vague and remote 'scientific' concept, but should refer to 'society' regarded as the local community, showing how better farming may produce more and better food.

The teaching of embryology

In some syllabuses for pre-university pupils the embryology section is reduced to such an extent that difficulties are increased. Embryology, as a science in itself, has a wholeness, a body of principles which emerge only from a sufficient study of details. Reduction of detail should not be carried too far.

Teachers and pupils are often unwilling to depart from the syllabus, but it is sometimes essential to do so. To reach real understanding of a topic may need more study than is indicated by a syllabus. Having decided upon the major principles, the next step is to arrange the practical work so that pupils know enough detail to arrive at these principles. Tabulation of the main story of vertebrate development may help to show what is required.

Main stages of vertebrate development:

(*a*) Fertilization initiates segmentation.

(*b*) The blastula is formed, a hollow sphere, containing the segmentation cavity.

(*c*) Invagination of one wall takes place.

(*d*) The gastrula is formed, having two cell walls, the epiblast and the hypoblast, and enclosing a new cavity, the archenteron. Elongation of the gastrula takes place and is accompanied by four major developments:

- (*i*) Formation of mesoderm.
- (*ii*) Formation of nervous system.
- (*iii*) Formation of notochord.
- (*iv*) Formation of gut.

(*e*) Differentiation in the three primary germ layers produces the various organ-systems.

(*f*) Each germ layer gives rise to certain organs, the more important derivatives of each being:

Ectoderm.	Epidermis and its appendages.
	The nervous system.
	Sensory epithelia in sense organs.
	Lining of stomodaeum and proctodaeum.
Mesoderm.	Connective tissues.
	Vascular tissues.
	Muscle tissues.
	Skeletal tissues.
	Reproductive and urinary organs.

Endoderm. Epithelium of gut.
Glands of the gut.

(*g*) The coelome is a cavity developed within the mesodermic tissues.

(*h*) Special membranes, the amnion and allantois, are developed which carry out protective, respiratory and excretory functions.

(*i*) The type and habit of life history (e.g. viviparity, metamorphosis) and the presence or absence of yolk may profoundly modify the various stages of this basal plan of development.

Now, although a syllabus may require 'a knowledge of the development of the chick embryo, up to the third day, as an example of vertebrate embryology', a study of the chick alone cannot enable the pupil to understand all these main stages. Thus there must be a judicious extension of study beyond the syllabus. The emphasis should be placed upon the development of the chick, but this should be seen in its relation to other examples which should be studied in broad outline. Experience suggests that embryology may best be considered under four headings:

1. Development of *Amphioxus* through early stages to show the formation and derivatives of the primary germ layers. This may be done with the aid of large diagrams and a series of models made from clay or Plasticine.
2. A brief survey of the development of the egg of the frog, to show the origin and derivatives of the germ layers.
3. The development of the chick up to the end of the third day, studied in the requisite detail.
4. A very brief survey of the early development of the mammalian embryo.

There are two further problems. Firstly, what special difficulties is the pupil likely to experience? Secondly, how may these be overcome so that the pupil gains a thorough understanding of his subject?

One difficulty, that pupils know too few details to be able to construct principles, may be overcome by the steps already proposed.

Terminology causes difficulty because it is unwieldy and confused by a multiplicity of synonyms. As teachers we must keep a minimum number of technical terms, explain what they mean and how they have been derived, and present a tabulated list of the more common synonyms.

Spatial relations are important in embryology and, as already mentioned, many pupils find difficulty in thinking in three-dimensional terms. The methods used to meet this may be outlined again:

1. *The use of models.* Beautiful scale models are available from commercial producers, but they are expensive. Where they cannot be bought, the teacher (helped by his pupils) should make models from clay, wax or Plasticine. Three types are required:

(*a*) Sectional models, each showing an embryo as though cut through along a particular plane.

(*b*) Models which may be taken apart by lifting off layers or pieces to show underlying structures.

(*c*) 'Plastic' models, made from clay or Plasticine, that may be moulded and manipulated to give a dynamic effect: for example, the edges of the neural tube may be pinched up and bent over to meet, and the tube depressed so that it is covered by the epidermis.

2. *Diagrams.* A series of simplified large-scale drawings should be made to illustrate the main principles of embryology. It is also useful to have stereograms in addition to the usual perspective and sectional figures. Since the details are studied mostly from sections cut in at least three planes (transverse, frontal and sagittal), it is also desirable to have accurate scale diagrams or photographs of these sections.

When pupils are making their own drawings they should not merely be engaged in copying, but in thinking. They may be required, for example, to construct a longitudinal figure from a series of transverse sections.

3. *Whole mounts.* Examination of microtome sections is essential, but should not preclude the use of whole mounts, which are

often valuable. These should be suitably stained and cleared, and mounted in 'hollow slides' (slides with a depression ground out, or with a circular wall of glass which retains mountant and specimen and is closed by a cover glass).

Another problem arises, in the study of embryology, from several occurrences taking place simultaneously and at different rates. Hence the specimens and sections used should always be of known age. Serial diagrams and moving picture films are also valuable in this connection. (The use of the film in the study of embryology has yet to be fully explored. For example, although it has been used for normal photography there appears to have been no attempt to make use of animated diagrams.)

In the case of the chick it is possible to observe the living embryo by the simple process of carefully opening the shell of a fertilized egg which has been allowed to stand in one position for some time. If the temperature is not allowed to fall too much, the embryo remains alive for a long period. (It is sometimes helpful to immerse the egg in warm normal saline solution.)

This chapter stresses certain important aspects of practical biology:

1. The significance of practical work as an aid to understanding.
2. The need to diagnose, locate and define the difficulties the pupil is likely to meet.
3. The need to define the content of each part of the practical course and to understand its relations with other parts, and to be certain that the detail studied is sufficient to make generalization legitimate.
4. The need to prepare and keep available a complete range of all materials which help the pupil to a more complete understanding, especially those which may help him to surmount his particular difficulties.
5. The need to encourage pupils to participate in the collection and preparation of specimens and illustrative materials.
6. The need to make clear the relations between the laboratory and the garden, and between these and society and its affairs.

7. The need to make practical biology, as far as possible, a study of life and living processes.

Details of certain practical procedures mentioned in this chapter will be found in Chapters VIII (laboratory methods) and IX (visual aids).

CHAPTER VII

THE BIOLOGY LABORATORY AND APPARATUS

In the early stages of school life, when biology is regarded simply as 'nature study', a laboratory is not necessary. Later, when biology is studied as part of 'general science', a special laboratory is seldom required. At the advanced (sixth form or pre-university) level, however, a separate biological laboratory is essential. The general problems of the laboratory and its equipment have been discussed in Volumes VII, VIII and IX of this series, and much of what is written there is relevant to the biology course. For advanced work some further points must be dealt with because biology makes demands of its own. These must be known and taken into account in the planning of the laboratory and other accommodation.

The laboratory surroundings

Access and nearness to garden. Under ideal conditions the biological laboratory adjoins the biology garden and has convenient access to it. This arrangement saves much time. Thus it should not be necessary to use school corridors, so saving time and reducing movement and disturbance. Access should be through at least two doors, or through folding partitions.

It is convenient to have an open-sided verandah, sheltered from rain and sun and with a hard floor. This is a useful extension of teaching space and is suitable for the setting-up and conducting of certain kinds of experiment. A verandah, however, must not be allowed to reduce the laboratory lighting too much, nor cut off the use of daylight for microscopy. If the laboratory is an end-room of a building, the verandah may be limited to one side only.

Beyond the verandah there should be a wide strip of concrete or 'tarmac', from which the main paths pass into the garden. This hard strip is useful after rain, allowing use of the garden more often than if there are merely grass paths. The dry walling, rockery and other artificially made ecological habitats are best placed near to the hard strip, making frequent visits possible even during wet weather. For the same reason hard paths, if they can be laid, are very useful.

Garden shed. The need of a shed, if only for the safe storage of tools, is usually recognized. If, however, the garden is to function as an outside laboratory, then there is need for more than a mere store.

So far as *storage* functions are concerned the major needs are likely to be:

(*a*) Space and racks for garden tools: hoes, rakes, spades, forks, etc.

(*b*) Space for one or two larger objects, such as wheelbarrow, buckets, baskets, folding steps or ladder.

(*c*) Space for supplies of chemicals, artificial manures, cement, etc.

(*d*) Space for supplies of sand, bricks, animal manure, humus, etc.

Of these, the first three require a watertight roof, but the fourth may consist of small, walled compartments covered by a light roof supported on poles. It may be found preferable to store animal manure at a distance from the shed, and the same may be true of a humus pit in which green stuff (plant tops, grass cuttings, leaves, etc.) is used as a basis of compost. (The rate of rotting may be accelerated by adding one of the many proprietary composting agents which are available.)

The *experimental* functions of the shed consist mainly of space for doing jobs which are too dirty or inconvenient for the laboratory: for example, potting plants, transplanting seedlings, mixing soil constituents, removing the soil from a ground crop such as manioc, weighing crop yields, etc. To facilitate such work a strong bench is needed. In addition there should be:

1. A spring balance weighing to 56 or 112 lb. by quarter pounds, or suitable metric units.

2. Scales weighing to 14 lb. by half-ounces, or suitable metric units.
3. A students' chemical balance.
4. Sieves with fine, medium and coarse mesh.
5. Baskets of various sizes.
6. Supplies of metal containers such as biscuit boxes, tobacco tins, etc.
7. Supplies of glass vessels: jam-jars, larger jars, etc.
8. A metre rule (for measuring lengths of fruits, leaves, etc.).
9. Measuring cylinders and a large graduated jug.

It is usually convenient to combine the experimental part of the shed with the storage of chemicals, etc. A cupboard with a lock is essential for poisons. (*Poisons must always be kept under lock and key.*)

Space must be found in the shed or store for keeping collecting gear. (Some simple examples of the latter are shown in Fig. 10.)

Greenhouse. A glass-house (or 'greenhouse' as it is usually called) is a necessity in temperate regions to provide a warm and moist climate for many exotic plants and the early stages of plant growth. It is equally useful in hot countries, especially in protecting plants from the drying conditions of sun or wind.

Greenhouses are built with a wooden or metal frame and the sides, ends and roof are then fitted with glass sheet. When built of wood the dimensions may be arranged to suit particular needs, but the wood is open to attack by white ants and other pests. This nuisance may be mitigated by the use of preservatives and fungicides, such as creosote, or by charring with fire the surfaces of posts which actually enter the ground.

The question of size must be decided in terms of needs and money. It should be noted that a very small greenhouse is uneconomic, because it offers little space at high cost. Where finance is a limiting factor a series of 'glass frames' may be used, as suggested below.

A door and one or two adjustable roof ventilators should be fitted. Along one wall there should be a bench, made of wooden

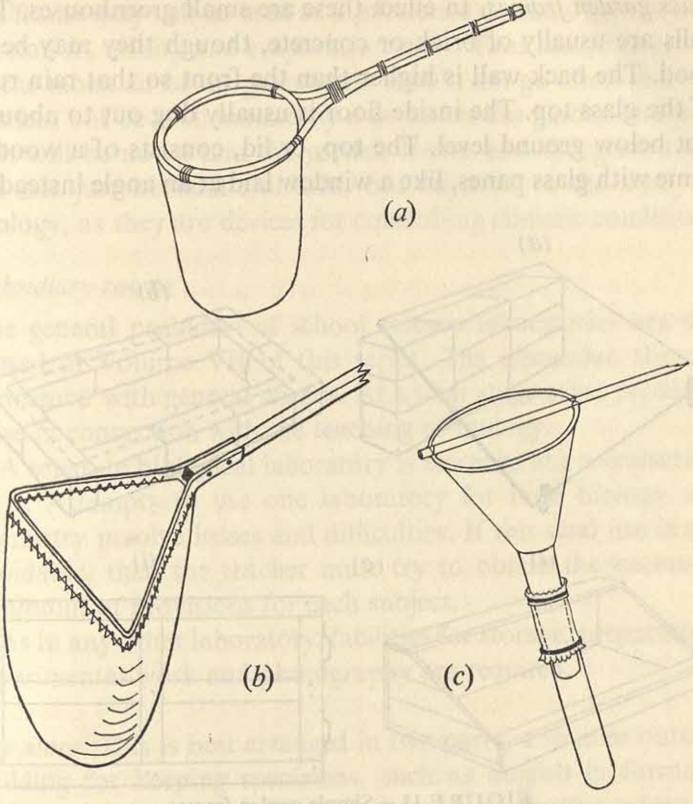

FIGURE 10.—Some simple collecting equipment

(*a*) The net is fastened to a single piece of supple cane bent and lashed as shown
(*b*) The net is sewn through the holes in a metal frame which is bolted to a wooden handle
(*c*) The wooden handle is wired to the metal 'funnel'. The boiling-tube is held in place by a cloth sleeve and rubber bands

slats or strips and about 30 inches wide. Along the opposite wall a series of shelves, arranged in tiers of three, is useful for smaller plants. The end wall, opposite the door, may be left free. Hanging baskets may be suspended down the middle line from the roof-tree.

The inside of the glass roof may be painted green or white, to cut down the heating effect. Alternatively, but at greater expense, split cane (bamboo) blinds may be fitted.

Glass garden frames. In effect these are small greenhouses. The walls are usually of brick or concrete, though they may be of wood. The back wall is higher than the front so that rain runs off the glass top. The inside floor is usually dug out to about a foot below ground level. The top, or lid, consists of a wooden frame with glass panes, like a window laid at an angle instead of vertically. If the size is small (say 3 by 2 feet), the top may be lifted on and off quite easily. Where the frame is bigger the top should be made in sections, fitted with suitable handles. (See Fig. 11.)

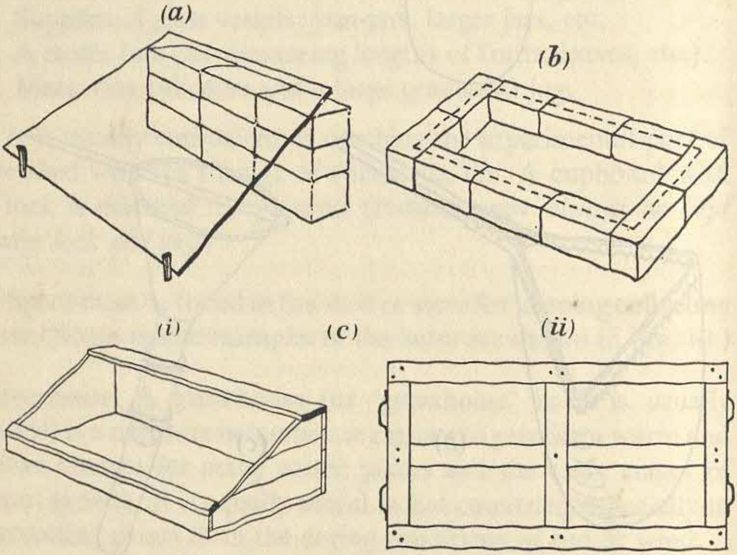

FIGURE 11.—Simple garden frames

(*a*) One edge of a sheet of glass is supported by bricks or stones. The opposite edge rests on the ground against pegs
(*b*) A sheet of glass rests on a framework of bricks
(*c*) (i) A wooden frame, with:
(ii) A glass top (windows in wood framework) with handles

In temperate climates the frame is used for 'hardening off' seedlings grown in the warmth of the greenhouse. They are kept for a time in the semi-sheltered conditions of the frame before being planted out in the open. This protection against severe cold is obviously unnecessary in tropical conditions. However, the frame may still be used as a protective device—against high insolation, aridity and evaporation rates. Thus seedlings grown in the moist air of the greenhouse should not go direct into the garden, but be acclimatized by a period in the garden frame.

It will be noted that the garden frame and the greenhouse are not just horticultural aids, but adjuncts to the study of ecology, as they are devices for controlling climatic conditions.

Subsidiary rooms

The general problems of school science laboratories are discussed in Volume VII of this series. The discussion there is concerned with general science. At a later stage other problems arise in connection with the teaching of biology.

A separate biological laboratory is essential at pre-university level. Attempts to use one laboratory for both biology and chemistry involve losses and difficulties. If this dual use is unavoidable, then the teacher must try to obtain the necessary minimum of provisions for each subject.

As in any other laboratory, facilities for storage, preparation, experimental work and photography are required.

The store. This is best arranged in two parts: a smaller outside building for keeping specimens, such as dogfish in formalin tanks and other materials which have a penetrating odour; a larger inside room, opening directly into the laboratory and to the outside as well, for specimens in jars, boxes of skeletal and other materials, apparatus, chemicals, etc.

The outside store may be as small as 12 by 8 feet. It requires a door, window and ventilator. A bench, 2½ feet wide and strongly built, should run along one wall below window level. It is convenient to have this covered with sheet lead on which pickled specimens may be directly laid. Below the bench should be the storage tanks raised at least 6 inches above floor level. These may be of porcelain, galvanized iron, or wood with a lead lining. Each tank should have a drain plug and an outside pipe with a tap.

On the wall opposite the window and bench there should be a series of strong open shelves for storing bottles, etc., with specimens and chemicals.

The inside store should be as large as possible, and at least 16 by 8 or 10 feet. It should be lined with shelves and a few cupboards, with locks, for the safe storage of chemicals, alcohols, etc. A series of racks are needed to hold glass tubing horizontally. (In large institutions, such as medical schools and technical colleges, double doors of sheet metal are often fitted, and the floor and lower part of the walls covered with sheet lead, as a precaution against fire.)

The preparation room. This should be as large as possible, and should have doors to both the store and the laboratory.

A service hatch between the preparation room and the laboratory is convenient. But apparatus may be damaged as it is handed from one person to another through the opening. Usually the apparatus may be carried through the door with greater safety by a pupil, the teacher or the laboratory attendant. A hatchway may be useful, however, in optical projection, especially back-projection. Noise is considerably reduced when the machine is in the preparation room. But, if a mirror is used, the operator cannot easily see the screen to focus the image. If no mirror is used the class usually has to turn round through 180°. When the preparation room is to be used for projection (not merely for storing projectors) it must be provided with:

1. Hatchway or door suitable for the light beam.
2. A bench, stand or table for the projector.
3. Wiring and supply board with appropriate carrying capacity.

Fittings in the preparation room should include:

1. Shelves for storing specimens and apparatus in frequent use.
2. Shelves for storing apparatus which is in the process of building or setting up; some shelves high enough for pressure injection.
3. Cupboards for storage.
4. A work bench, if possible lead-covered, as large as possible.
5. Two sinks, large, rectangular and deep.

6. Multi-nozzle water taps.
7. A gas supply with sufficient two-way taps.
8. A gas blow-pipe for glasswork.
9. A set of basic hand-tools for the repair and construction of apparatus.
10. An analytical balance and a students' balance for use in the preparation of solutions.
11. Apparatus for microtomy.

This list offers suggestions for the general needs of a biological preparation room, and it should be modified to suit local needs and particular interests. Indeed, the most effective way of determining what is necessary for a preparation room is to list the kind of work to be anticipated. For example:

The cutting and staining of microscopic sections.
The preparation of museum specimens.
The preparation of skeletal materials.
The making of injections.
The carrying out of dissections.
The construction of special apparatus.
The setting up of experiments.
The manufacture of visual aid materials.

Such preparation work not only takes much time, but needs a lot of space. For example, the injection of the blood-vessels of a mammal, or dogfish, under gentle pressure, may require several days and, as the work must be left set up, the space is unavailable for other work during this time. Hence it is necessary to make economic use of the available space and in particular to make the bench space as large as possible.

The bench may be divided into zones. Some must have a definite function, such as glass-blowing, in which the blow-pipe, as a fixed instrument, prevents multiple use. Other zones may be of general use, because processes such as dissection or the construction of apparatus do not demand fixed apparatus. For wood-work and metal-work the vices and bench-stops, to some extent, impose a fixed function.

It is also essential to ensure that the *sinks* are large and have efficient traps on the siphons. Work in the preparation room produces debris which may cause endless trouble unless the waste system has efficient traps.

Above the sinks there should be particularly strong shelves, big enough to permit their use for pressure injection, in which it may be necessary to run off waste water.

Although sinks are often placed at the end of a bench, it is preferable, when two are installed, to have one at the end and one in the middle. The latter may then be used from both sides, a great convenience if the water supply is needed for two purposes, at the same time: for example, filtration and aeration.

The *analytical balance* should not be left on the bench top, where it may suffer damage or be liable to vibrations. It is better kept on its own bench, pillar or slab. Placed in an artificial recess, formed by flanking it with two cupboards, it is protected from damage when large apparatus is moved about. Suitable illumination must be provided for the balance case.

Some of the *cupboards* should have solid doors to protect their contents from the action of light. Others should have glass doors, so that the contents may be seen and located. Sliding doors are convenient and save space, but unless they are well made, with seasoned timber, they may easily stick or become stiff. All cupboards need ventilation, which is easily provided by a series of large holes covered by fine-mesh wire to prevent the entry of rodents and cockroaches.

Dark room. A dark room is needed in biological work for experiments involving light-dark response, photosynthesis, etc., as well as for photography. Providing that ventilation is efficient and that plants are protected from the injurious effects of any chemicals, one room serves both purposes.

The door may be light-trapped. The use of double doors is effective, but adds to the expense and, if the doors are opposite to each other, light may enter under the bottom edges. This may be prevented by a batten of wood nailed to the floor inside, acting as a door stop and light trap. An alternative is to have overlapping of the walls to cut out light. A cheap method, effective if used carefully, is to drape a single door with black curtains on both sides.

It is convenient to be able to open a window to let in light and air, but this window must have an efficient light trap, in the form of a folding door or flap inside the window. The shutters, or louvres, are arranged to admit air, but exclude light. If one pane of glass is removed and replaced by a sheet of wire mesh there is a constant circulation of air.

Despite its value in education, especially in connection with science, the cost of photography precludes its use on an extensive scale. However, even a simple camera is of value, and every biological laboratory should have one, together with a simple enlarger. For photographic work in the dark room a bench with a large sink and a supply of running water must be provided. The enlarger may be placed at one end of the bench and the sink at the other, with the intervening space used for developing and printing positives and negatives.

Electric current is desirable, but not essential. Enlarging may be done by daylight, or by an incandescent mantle lit by gas or pressurized paraffin. Dark-room lamps may be operated by electric current from a battery or even by a candle. Shelves are required for storing photographic materials.

For biological work in the dark room a second bench is needed, and a series of shelves with spaces large enough for plant specimens and fitted with doors to keep out light when the dark-room lamps are in use. For some experiments it is useful to have the cupboard doors arranged to hold sheets of glass of different colours, which may be interchanged or replaced by opaque sheets of metal or wood.

The laboratory

Biological work tends to make more mess than other science work, and there are more waste materials to be disposed of. Apart from this, the general principles of laboratory design, as described in Volume VII of this series, are applicable.

Dealing with waste. Waste material, of plant or animal origin, if allowed to accumulate, decays, gives off unpleasant odours and attracts flies and other pests. If disposed of carelessly it may block up the waste system. Careful provision must be made to avoid this.

Sinks should have large-diameter waste-pipes with removable sieves (filters) at the top of the exit pipe. These should be arranged so that a stopper (plug or plunger) may be fitted with the filter in position. (If the filter has to be taken out before the plug is inserted, removal of the latter from a sink full of water and debris may cause blockage of the pipes.) At least one sink in the laboratory should have a removable wire cage or basket as a complete internal lining, like an open box. All dissecting boards, etc., should be washed and thoroughly drained before being put away.

Traps. Waste matter, especially small particles, is usually trapped in a U-tube fitted with a plug in the lower surface at the bottom of the curve. Although this provides an efficient trap it has to be dismantled for cleaning. An alternative is to arrange for all waste water to be carried away by large-diameter pipes, with a vertical fall, into a main waste channel. This should not be done unless the sinks have efficient internal filters.

Bins. The laboratory requires at least one waste bin into which solid material is tipped. The bin should be of metal, preferably in white enamel, and should be kept clean. The lid should be operated by a foot pedal and inside there should be a wire mesh lining with lifting handles. This bin should be emptied into the waste pit or incinerator at the end of each day. Twice a week it should be thoroughly scoured with a stiff brush and water. A few drops of a strong disinfectant should always be dropped in after cleaning.

Water supply. An important need from the biologist's point of view is to have a continuous water supply. Thus the main supply tank should hold at least a thousand gallons and have a head of twenty feet.

The main tank, and any subsidiary tanks, should be provided with closely fitting inspection covers, to prevent the entry of dirt and the breeding of mosquitoes. The inlet pipe from the mains should have a screw-down stop-valve, conveniently placed for easy and quick access. There should also be the usual automatic devices for controlling water-level, and a drain tap at the bottom of the tank.

There should be another main screw-down stop-valve or turncock to cut off the supply as it enters the biological laboratory, so that secondary taps may be repaired without cutting off the supply to other rooms.

Each sink should be provided with water through the standard tap fitting with two or three outlets. In addition a wall-tap should be available, about three feet from the floor, for filling buckets, etc. It is convenient to have a shallow drip tray or sink, in which to stand the buckets on the floor.

Sinks may be arranged in many ways, but the practice of having only two, one at each end of a long bench, is seldom satisfactory. Nor, from the point of view of the biologist, is the provision of very small sinks.

It may be necessary to filter the water supply, if not continuously and completely, at least upon some occasions. For this purpose use may be made of the normal double-walled filter and 'candle'; or of the more recent types of filter which may be attached directly to the tap. This is expensive but very desirable, especially where photographic work is undertaken. Sediment, and rust particles in particular, often cause considerable wastage of plates, films and bromide paper.

Benches. Benches for biological work are preferably built of well-seasoned teak. Although a 'one-piece top', in which the bench top is a single wide plank, is often considered essential, this is not so. The top may be made from two or more planks and is quite satisfactory, provided that the jointing is watertight. No joint prevents liquids from dripping through into the cupboards or drawers below unless the timber is thoroughly seasoned.

Bench tops are best left in a natural state after working to a fine finish. (Although the modern cellulose varnishes are excellent, they seldom stand up to prolonged laboratory usage.) The wood should have boiled linseed oil well rubbed in and then be wax polished. Both oil and wax should be applied sparingly.

Wide benches, supposed to accommodate pupils down each side, are usually less satisfactory than narrower ones with seating along one side only. The latter arrangement allows all pupils to face in the same direction, and is particularly convenient when the benches are intended for work in microscopy by daylight.

Each pupil should be provided with a drawer and, apart from space devoted to sinks and leg spaces, all other available space below the benches should be used for storage. Movable or built-in lockers (cupboards) with shelves and drawers are recommended.

It is a great convenience to have a place specially prepared for projection drawing with the microscope or micro-projector, and for tracing. A suitable arrangement consists of a cupboard below the bench top, in which is a glass plate with a hinged protective cover of wood. Inside the cupboard there must be a suitable electric point, a microscope lamp, and space for the microscope to stand on a shelf which may be set at different heights in a series of slots. A real image is focussed on to a sheet of tracing-paper laid on the glass plate and used for demonstration or for making an enlarged drawing. It may be necessary to screen the projection plate from window light.

Many teachers prefer to arrange the microscope or micro-projector on a shelf or stand above the bench and project downwards on to the bench. This offers less protection to the apparatus, but makes it easier for the observer to see the image while adjusting the focus.

Racks, shelves and cupboards. Adequate provision of racks and cupboards is necessary for good organization in the laboratory. It ensures that materials are readily available for use and that they are protected from damage when not in use. Shortage of suitable and convenient storage space is one of the commonest faults in laboratories.

Racks are needed for tubing, test-tubes and other glassware, such as pipettes and burettes. Some of these should be kept in the preparation room, but some must remain in the laboratory. For glass tubes the rack should consist of a series of long narrow shelves with an edge piece at the front to prevent the tubes from rolling off. For burettes it is wise to divide each shelf into single spaces, each containing a single burette, to avoid damage to taps and delivery tips.

For test-tubes a simple method is to keep the main stock in its original packing in the store or preparation room. In the laboratory a subsidiary stock may be kept on a shelf divided into a series of cells, each containing a single size. The tubes in regular use may be kept in the usual form of test-tube rack on the bench.

Shelves are needed for specimen jars, bottles of reagents, etc. Dimensions must be suited to the type of container. It is convenient to have lower shelves arranged to take large bottles* and higher shelves for smaller bottles.

Cupboards are required for storing specimens which are delicate, costly, or liable to damage, or for costly or dangerous chemicals. Strong internal bolts should be fitted, together with a strong lock. Some of the storage cupboards may be underneath the working benches, and others in standard cabinets.

For special materials, such as herbarium specimens, filmstrips, lepidoptera, microscope slides, etc., it is wise to have cupboards built locally to meet particular requirements. The dimensions should depend upon these requirements. Seasoned timber should always be used.

Apparatus

What may be called the 'standard apparatus' for pre-university work is given in Appendix A. In tropical countries one item should be added, if possible, as it greatly increases the range of experimental work. This is a refrigerator, which may appear to be a luxury, but is of considerable value in physiological experiments and demonstrations and may be regarded as essential for some kinds of work. Kerosene-operated models being available, electric current is not essential.

In addition to apparatus usually purchased, some may be made in local workshops, in the school handicraft centre, or by pupils in the biological laboratory. Making apparatus locally leaves funds available for special purchases, provides apparatus outside the range of standard products, and permits exploration along unusual lines.

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* For example 'Winchester Quarts', about 2½ litres.

One criterion should be applied to any plan to produce 'home-made apparatus': it should have a positive value in teaching and learning; it must be an aid to the learning of biology and not merely a preparation of gadgets.

Apart from assembling a small collection of suitable hand tools and acquiring some skill in elementary constructional work, the teacher should make a practice of collecting every form of 'junk'. Sheet tin and other metals, metal tube and rod, broken clockwork mechanisms, odd lenses, etc., are always useful. The skills required are few and simple: the use of chisel, plane, saw and drill for wood, and of hack-saw, file, drill and soldering-iron for metal work. Every teacher of science should, of course, have some skill in glass-blowing, even if no more than the ability to join tubes and make T-pieces and U-tubes.

Some examples of apparatus which may be made in the school are described below. At some stage all depend upon scrap material, or a standard item which determines the dimensions. Dimensions are seldom given, as each teacher must adapt his apparatus to the material on which it is based.

Photographic apparatus. The potential value of photography to the teacher of biology is so great that determined attempts should be made to exploit it. The kind of work likely to be undertaken is:

(*a*) Photo-micrography of slides and microscopic living specimens.

(*b*) Close-up photography of small specimens such as insects, shells, etc.

(*c*) The copying of diagrams.

(*d*) Location photography, out of doors, to record ecological conditions, field experiments, individual plant specimens, etc.

(*e*) Photography of animals in natural surroundings.

Such a list suggests a variety of photographic apparatus which is likely to be very expensive. Consequently photography is often ignored and pupils are denied a most useful aid. Yet, within certain limits, much of this work may be carried out by simple means. Reference to some of this is made in Chapter IX, here the concern is with other aspects.

Close-up photography, whether concerned with small specimens of macroscopic size, or with the copying of diagrams, requires:

(*a*) A camera with a sufficient extension to permit close work.

(*b*) Supplementary lenses to give a magnified image. (An alternative to (*a*).)

(*c*) A copying stand offering rigidity and convenience of handling.

(*d*) Even illumination, which may be readily controlled.

The camera may be purchased, adapted or constructed. It is convenient to be able to take a photograph and process it at once, not only as an immediate check, but because it is often concerned with a single experiment or specimen. It follows that a plate camera (using single plates) is very useful. Old-fashioned plate cameras may often be purchased cheaply at second-hand, or a simple kind may be made. Quarter-plate size (4¼ by 3¼ inches) is suitable, as this reduces bulk and cost.

At least two parts of a camera have to be purchased: the plate-holder and the lens-shutter assembly. The most convenient procedure is to buy, through any reputable dealer, a single metal or wooden plate-holder. This consists of a body, holding the plate, and a draw-shutter, which protects the plate from light, except during exposure. Round two sides and one end of the plate-holder is a flange, which slides into a recess on the camera back. The construction of a camera centres around this, since it is the main element to be purchased.

A basic design for a very simple camera is as follows:

The camera *back* is screwed to the base-board at right-angles, and the plate-holder slides in the grooves at the back. These should be made from brass or aluminium strip for a metal plate-holder, which has a knife edge, or they should be cut as rebates in the camera back for a wooden plate-holder.

The camera *front* must be at right-angles to the base-board, and free to move along a slide, so that its distance from the back of the camera may be altered, that is the camera may be focussed. The sliding action is easily arranged if the camera front has a base-piece to run between two guide strips at the edges of the base-board.

The length of the camera *base-board* should be at least twice the focal length of the lens used, preferably three times as long. This allows small specimens to be photographed at slight magnification.

Bellows are needed to join the back and front of the camera and exclude light. In cross-section they must be a little greater than the plate size and they must be long enough to permit extension to the full length of the base-board. Bellows are usually made from leather and may be purchased. They may be made, however, from good quality paper and cloth by the following method. A sheet of good pliable brown paper of sufficient size is pasted on a piece of fairly stiff muslin. On the paper surface are drawn the lines along which folds have to be made. The paper is then folded, taking care to prevent tears or cracking, first working across the paper and then putting in the corner folds so that the bellows become like an open-ended box. The overlapping edges are glued together, and then the bellows are glued to the back and front of the camera body. (See Fig. 12.)

An alternative procedure is to replace the bellows by a rigid box body, made in three sections. One section is attached to the camera back, another to the camera front, and both these slide inside the third (middle) section. The lengths must be such that, when closed, the total (measured between the lens and the plate) is about 5 per cent less than the focal length of the lens.

In *focussing*, a sheet of ground glass is slid into position in the plate-holder grooves in such a way that its ground surface is in the same plane as that to be occupied by the sensitive surface of the photographic plate. It is essential to ensure exact register. This is done by glueing very thin strips of wood round the edges

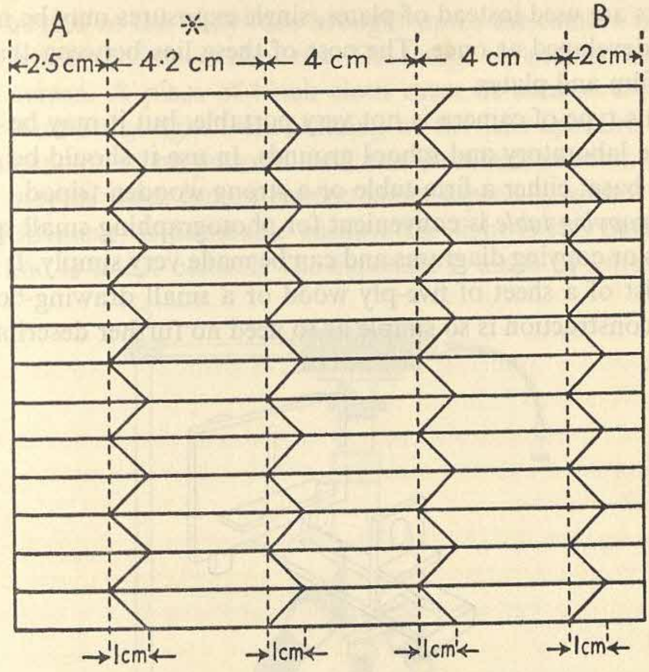

FIGURE 12.—Marking out paper for making bellows. * Slightly longer, to allow A to overlap B. Dimensions for projection from 24 × 24 mm. positives of 2 × 2 in. slides. They can be modified as required

of the focussing screen. An alternative, which increases the cost but provides protection, is to use a plate-holder in the back of which a rectangular aperture has been cut and from which the draw slide or cover is removed. This ensures exact register.

The *lens and shutter* may be purchased from a second-hand dealer or removed from an old camera. Even the simple lens of a large-sized (quarter-plate or postcard) box camera may be used, and this has the advantage of a simple shutter. An old 'R.R.' (rapid rectilinear) lens in one of the old compound shutters is admirable for the purpose.

Roll film may be used in such a camera. It is necessary to buy a roll film adapter, of suitable size, matched to the same register as the metal or wooden plate-holder. Roll film is cheaper than plates, unbreakable and less bulky, but it does not offer the same convenience in regard to single exposures. However, if cut film sheets are used instead of plates, single exposures may be made and developed at once. The cost of these lies between that of roll film and plates.

This type of camera is not very portable, but it may be used in the laboratory and school grounds. In use it should be on a rigid base: either a firm table or a strong wooden tripod.

A *copying table* is convenient for photographing small specimens or copying diagrams and can be made very simply. It may consist of a sheet of five-ply wood or a small drawing-board. The construction is so simple as to need no further description.

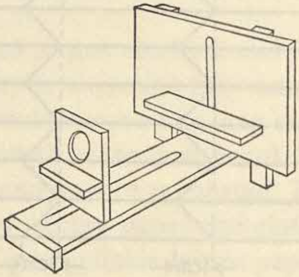

FIGURE 13.—A simple photographic copying stand.

The stand is shown in the horizontal position. The object is placed on the shelf on the base-board seen here upright. The camera is placed on the other shelf, the lens pointing through the aperture. Both shelves slide in slots with screws and wingnuts to fix position

The joints should be well made, glued and screwed for rigidity. For copying diagrams or photographing objects which lie on a flat surface the stand is placed in a vertical position. For such things as flowers it is placed horizontally, with the object on a shelf, the height of which may be adjusted. (See Fig. 13.)

The camera holder must be suited to the camera in use.

Photo-micrography may be carried out with any focussing camera by the simple device of setting up the microscope for visual observation in the usual way and placing the camera, focussed for 'infinity', over the eye-piece. Exposure is a matter for experiment. (See Fig. 14.)

The simply made camera already described may also be used. The microscope is placed horizontally, the eye-piece removed, and the end of the body tube brought up to the camera front, from which the lens is removed. The image is focussed on the glass screen. A piece of black cloth must be used as a mask to prevent stray light from entering at the lens aperture. The illuminant must be powerful and the illumination even. Sunlight may be used, but an electric lamp, especially with a very small filament, is preferable because the light is less likely to vary and is under control. The exposure is made by switching the light on and off and not by using the draw shutter of the plate-holder, in order to avoid the risk of vibration. (See also p. 240.)

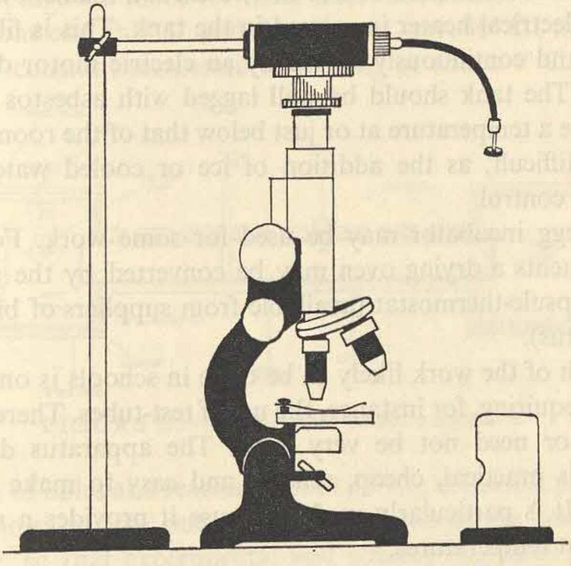

FIGURE 14.—An arrangement for photo-micrography. The camera is supported above the microscope

Apparatus for temperature control. There are many experiments, especially in physiology, which should be carried out by pre-university pupils, but are often neglected owing to lack of suitable apparatus. Some of this apparatus may be made by fairly simple means.

An incubator is required to provide a constant temperature.

A fairly satisfactory arrangement is a large tank of water, kept well stirred and with hot or cold water added as required to keep the temperature steady. The temperature varies a little, of course, and the apparatus requires constant supervision, which is a nuisance even for short periods.

Many textbooks of physical chemistry describe how a constant temperature tank may be made. A mercury–toluene thermostat is used to control the heating device, which may be a gas jet below the tank or one or two carbon-filament lamps or other electrical heater immersed in the tank. This is filled with water and continuously stirred by an electric motor driving a mixer. The tank should be well lagged with asbestos felt. To preserve a temperature at or just below that of the room is even more difficult, as the addition of ice or cooled water needs further control.

An egg incubator may be used for some work. For other experiments a drying oven may be converted by the addition of a capsule-thermostat (available from suppliers of biological apparatus).

Much of the work likely to be done in schools is on a small scale, requiring, for instance, the use of test-tubes. Therefore the incubator need not be very large. The apparatus described below is practical, cheap, reliable and easy to make or have made. It is particularly useful because it provides a range of constant temperatures.

The principle involved is that of heat conduction. If the two ends of a conductor are kept at constant different temperatures, there is a constant temperature gradient between them. The apparatus consists of two end boxes connected by a barrel about 4 inches in diameter and 4 feet long. (See Fig. 15.)

The end boxes must be watertight, and two 7-lb. biscuit-tins are very suitable. They should be well lagged with felt and, if possible, fitted into a wooden case. One box is fitted with a thermostatically controlled heater. This box is preferably filled with water and may be heated electrically or by gas, but the use of water demands some very accurate sealing of joints. The other box contains ice.

The barrel joins the two boxes, projecting about an inch into each, and has its ends closed by metal discs. Copper is ideal but expensive. However, a length of stack pipe (cast-iron rain-water pipe) may be used. Along the upper surface pairs of holes are bored side by side with the drill at right angles to the barrel. The pairs are about 3 or 4 inches apart. The holes are of a size to take a convenient test-tube, for example $\frac{5}{8}$ inch diameter. The whole barrel is lagged with asbestos clay, leaving the holes clear, and wooden plugs are made for those holes not in use.

With one end at 0° C. and the other at, say, 40° C., there is a range of constant temperatures starting at about 4° C., in the first pair of holes and reaching about 35° C., at the last pair. The paired holes in any one position are each at the same temperature, so that experimental and control test-tubes may be used, as in work on enzymes or where thermo-barometric compensation is required.

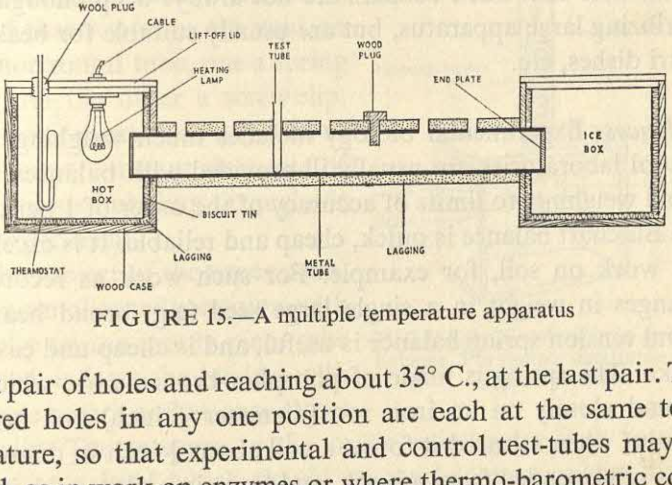

FIGURE 15.—A multiple temperature apparatus

Such an apparatus may be used for demonstrating the effect of temperature variations on enzyme activity, on respiratory rate, on rate of seedling growth, on time of hatching of small eggs, and so on.

It is also a useful apparatus when used in conjunction with the respirometer, provided that the holes are of a suitable size and the main tube has a sufficient diameter.

Sterilizers. Stress has been laid on the need for biological work to be closely related to social needs and problems. For this reason attention should be given to elementary work in bacteriology. If this is to have the proper practical basis, it is necessary to be able to sterilize Petri dishes and similar glassware.

Simple boiling is moderately effective, but exposure to steam, at above 100° C., is better. An autoclave is not often needed in schools and the expense cannot be justified. But an efficient method, suitable for school work, depends merely on a large saucepan or fish-kettle. Apparatus to be sterilized is placed on a rack so that it lies in the steam space. If the pressure rises too high the lid lifts.

An alternative is to make use of a domestic pressure cooker of suitable size. Such cookers are not always deep enough for sterilizing large apparatus, but are usually suitable for beakers, Petri dishes, etc.

Balances. Experimental biology includes much weighing, and school laboratories are usually ill-provided with balances. For rapid weighing, to limits of accuracy of the order of 1 per cent, the Butchart balance is quick, cheap and reliable. It is excellent for work on soil, for example. For such work as recording changes in weight in a single large seed (e.g. broad bean) a spiral tension spring balance is useful, and is cheap and easy to make. The spring is made of phosphor-bronze wire, which is wound closely on an iron rod (diameter $\frac{3}{8}$ inch) and heated lightly; when released it forms a coil about $\frac{3}{4}$ inch in diameter. This is suspended from a hook, and hung in a glass tube inside a box. A tray, of aluminum foil, is hung at the bottom of the coil. A cross-beam of glass filament, fastened on by sealing-wax, and a strip of mirror, eliminate parallax error in reading the spring extension. By varying the gauge of wire and the length of the coil, different degrees of sensitivity and total load are obtained. Before reading, the pointer must always be set at zero by using the top suspension hook, which is adjusted in the cork at the top of the glass tube. Calibration is done with the aid of fractional weights from a standard set. (See Fig. 16.)

The study of respiration. A study of respiration includes fundamental metabolism and is thus a step towards the understanding of physiology. Although respiration receives attention in the school laboratory the work is often only qualitative. Quantitative work may and should be carried out, as the apparatus needed is both simple to construct and easy to use. It is an interesting apparatus* consisting of a mercury manometer, a football bladder, a mouth-piece and a tube of alkali connected together. The tube contains 25 c.c. of N/500 caustic soda and a few drops of phenolphthalein. To facilitate observation a comparison tube of water is used, and both tubes lie in front of a matt-surfaced white card. It should be noted that two clips are used on the horizontal tube, one a spring clip and the other a screw clip. The latter must be so adjusted as to allow a constant slow rate of continuous bubbling throughout the experiment.

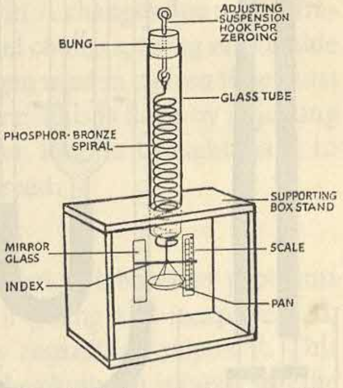

FIGURE 16.—A simple micro-balance. For further details see description in text

The subject of the experiment, in a normal rested condition, with the clip on the mouth-piece tube opened, inflates the bladder with a single breath and at once closes the clip. The mercury in the outer manometer limb is now raised to a level which should be marked by a rubber band wound round the tube. The subject's pulse rate should be counted against a watch and recorded. The spring clip on the horizontal tube is then opened allowing the expired air in the bladder to bubble through the alkali. The time taken to remove all trace of colour is noted. A useful precaution is to leave the alkali tube off at first, and to use the bladder pressure to blow a puff of expired air through the apparatus to remove residual atmospheric air. The tube is then placed in position and the time for decolorization noted, as described above.

The subject now engages in vigorous exercise for 30 seconds, and the experiment is repeated. The manometer level must be brought to the marked level and the bladder pressed flat before the experiment. Further repetitions are made after 60, 90, etc. seconds of exercise.

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* Described by G. N. Ridley in the *School Science Review*, 1936.

Two graphs may be plotted: pulse-rate, and time for colour-change (a measure of carbon dioxide), against length of time of exercise. The relationships between them may then be discussed.

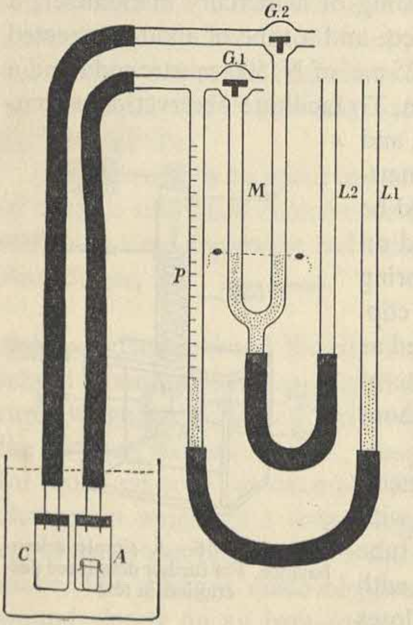

FIGURE 17.—A respiratory apparatus. (This is based on Haldane's blood gas analysis apparatus.) Note: The clips mentioned in the description in the text are here shown as glass taps, G.1 and G.2

A modified form of Haldane's gas analysis apparatus has been found very suitable for use in school biology laboratories. The apparatus, shown in Fig. 17, is based on a 1 c.c. pipette graduated in tenths and hundredths. This pipette (P) is attached by thick-walled rubber tubing to a levelling tube (L.1), at its bottom end, and to a respiration chamber (A) and one side of a manometer (M) at its top end. The manometer has a levelling tube (L.2), and its other limb is attached to a control chamber (C). Both limbs of the manometer communicate with the atmosphere through tubes fitted with spring clips. The respiration chamber (A) and the control chamber (C) must be of the same volume. They may conveniently consist of test-tubes of a diameter suited to the multiple-temperature thermostat already described. Equal volumes of a carbon dioxide absorbent are placed in each tube, and the living tissue, the subject of the experiment, is put in the control chamber (C). As both are of the same volume and at the same temperature there is complete thermo-barometric compensation, changes of pressure and temperature having equal effects upon the experimental chamber (A) and the control chamber (C).

Experiments are conducted as follows: the manometers are filled with coloured fluids, the absorbent is placed in the tubes, the tissue is placed in the experimental chamber, and both tubes are put in the constant temperature bath, with the clips open. When thermal equilibrium has been reached, (L.1) is adjusted until P reads zero, and the manometer level is marked by a thread stretched between two pieces of wax. The top clips are then closed simultaneously. The volume in A changes due to respiratory activity and the manometer level changes, rising on the side connected to A. The volume of oxygen used in a given time must be measured at atmospheric pressure. This is done by adjusting (L.2) and (L.1) until the manometer level is brought back to the original level marked by the thread.

Further practical laboratory problems

Even with the above summary of practical laboratory problems as a guide, the teacher, especially if young and inexperienced, may easily find himself in difficulty regarding equipment. This may be the case where educational development is rapid and the teacher finds himself faced with placing orders for apparatus which must be as complete as possible in order to avoid waste of time. It is also necessary to consider economics and efficiency. In brief, there is need for some guiding principles in the ordering of equipment. Through the kind co-operation of the Ministry of Education of the Ceylon Government, and of Mr B. J. P. Alles, who was wholly responsible for the scheme, it is possible to reproduce here some relevant material.

The basic argument, briefly presented, is that because science is an accumulative, progressive and systematized body of knowledge, arrived at by observation and experiment under controlled conditions, the laboratory equipment needed falls into such groups as:

Group 1 *Observational aids*—microscopes and other apparatus designed for qualitative or quantitative observation relating to structure, mass, length and time, or simple functions of these and other units, e.g. electrical units.

Group 2 *Control aids*—equipment necessary for controlling or providing the fundamental conditions, such as life habitats, temperatures, lighting, pressures, volumes, etc.

Group 3 *Materials*—the specimens used by the biologist, the consumable materials like chemicals, etc.

Group 4 *Teaching aids*—prepared specimens, charts, diagrams, films, film-strips, etc., and apparatus needed for their use and demonstration.

Group 5 *Auxiliary aids*—the various things needed for supporting, containing, storing (stands, clamps, bottles, beakers) or rearing (cages, tanks, etc.).

Group 6 *Tools*—for maintenance and repair.

Such a classification has shortcomings because many items are multi-functional and thus fall into more than one group. However, it provides a preliminary framework for thinking along two other lines.

Firstly, the exigencies of economics and the demands of efficiency suggest that all items of equipment may be placed in one of three categories:

Category I Essential items, without which work cannot be done.

Category II Apparatus desirable for the achievement of high standards of work.

Category III Items which are useful, if conditions permit their purchase.

(A razor for cutting hand sections is, for example, *essential*; a rocking-microtome is *desirable*; but the more expensive rotary microtome may only be considered *useful*.)

Secondly, the number or quantity of any item requires careful thought, and it is here that the young teacher often finds his chief difficulties. The situation may be considered in terms of two main factors:

C—the seating (or working) capacity of the laboratory.
S—the number of students involved.

The number or quantity of any item may be:

(*a*) independent of both C and S
(*b*) a simple function of (directly proportional to) C or S
(*c*) a complex function of C or S or C and S.

With these guiding principles in mind the equipment necessary for school science may be divided into four main sections:

Section 1 Items of which the number or quantity was considered to be independent of C and S.
Section 2 Items considered to be dependent on C, but not directly proportional to it.
Section 3 Items directly proportional to C.
Section 4 Items independent of C but proportional to S.

No scheme is perfect, but experience has shown that such a framework proves useful. The actual results of its use will vary, for not only will they be functions of C and S, but also of such variables as geographical location or the examination syllabus. In Appendix A are equipment lists, prepared on the above basis. Tools are shown in Appendix D.

The efficiency of a laboratory not only depends upon its resources and equipment, but also on how these are used and maintained.

Usage involves not only the rate of consumption but also care in handling. *Maintenance*, of which the first step is care in handling, goes beyond this to routine examination, repair work and protective storage. The work involved in achieving careful usage and efficient maintenance is not excessive and amply rewards the efforts made.

So far as the rate of usage of consumable materials is concerned the only guide is carefully recorded experience combined with vigilance against wastage. If possible, each different item of consumable material should be entered on a separate stock card. This sheet might provide spaces, suitably arranged, for recording the following data:

1. The name of the material.
2. The source of supply.
3. Dates of ordering and delivery (the differential is an index of how far ahead a new order should be placed).
4. Original quantity.
5. Quantity remaining on successive dates (i.e. monthly, termly, etc.).
6. Size of class (or total of all pupils) using material.

While it is possible to enter all this on a standard 5″ by 3″ library card it will be found that a larger card of 6″ by 4″ or 7″ by 5″ is more convenient. As time passes and data regarding consumption rate is collected, it becomes possible to draw up a predictive order guide. This, an analysis of the various rates of consumption, can most easily be prepared on one or more foolscap sheets. It should act as a reminder to place orders in good time.

In schools where orders are made annually, at times perhaps determined by the educational authority, it is none the less desirable to keep such records. They act as a rational guide to ordering, a check on consumption rate and a corrective to the too common habit of over-ordering.

Efficient storage is an important item in the prevention of wastage. So far as consumable materials, such as chemicals, dyes, reagents, etc., are concerned, special attention should be paid to containers. Reagents which are affected by light should be kept in dark glass bottles or jars, in a dark cupboard. Powders and crystals are often delivered in paper packages or tins. In both cases they should be removed into suitable jars (glass is moisture-proof and does not rust). However, the caps may rust, but this can be reduced, if not prevented, by the use of an anti-rust paint. Many teachers have found it possible to collect (with the aid of pupils) a large supply of domestic glass containers with plastic or aluminium caps. Polythene bags are also a useful modern by-product of domestic life, and they are available, new or used, in most large towns.

In regard to the storage of laboratory equipment, attention has to be given to such questions as rusting and the attack of fungi, moulds, etc. The surfaces of ferrous metals should be painted. Where this is not possible, they should be wiped over, lightly and frequently with a soft rag bearing a trace of good quality, thin machine oil. Glassware should be stored on suitable racks, in shelves, cupboards, etc. Optical glass, such as lenses, prisms, objectives and eye-pieces, requires special care. The essential thing is to protect it from fungal attack which, however slow, is insidious and persistent.

It is in regard to the microscope, micro-projector and various projectors that the problem is acute. In some cases it may prove impossible to take any very special precautions, but at least such instruments can be placed in safety, under dust covers in cupboards with a free flow of air. They should (apart from normal use) be constantly removed, inspected and cleaned, using nothing but lens tissue paper or the softest possible fabric for the glass surfaces. Best of all, the optical elements should be removed, when not in use, and stored in desiccators with a desiccant. (An indicator to show when the desiccator no longer dries the air is an advantage.) Silica gel, in granulated form, is convenient and recoverable by heating. Checks should be made with a dial-type hygrometer when possible. It is an added advantage if the desiccator can be exhausted by an air-pump.

The microscope is such an essential instrument in biology, that every effort should be made to ensure its care, maintenance and proper usage. Some suggestions regarding these instruments are given in Appendix B which reproduces, with the kind permission of the Government of Ceylon, some notes prepared for the use of teachers.

The maintenance and repair of laboratory apparatus calls, at intervals, for some degree of skill in the use of hand tools. In schools with metal shops and wood-working shops, it is possible to obtain the services of specialist teachers. Apart from this, however, it is desirable that every biology laboratory should be equipped with a small collection of simple hand tools and that the teacher should be able to use them. Teachers without suitable training can develop the necessary skill with a modicum of practice.

The kinds of activity involved fall mainly into the following groups:

(*i*) *Elementary wood-work*—for repair and making of boxes, stands, supports, etc. The major operations are the marking out of work, sawing, planing, finishing, making simple joints, boring, painting and varnishing.

(*ii*) *Elementary metal-work*—for repair or making of stands, models, etc. Most of the work is with sheet metal and wire: marking out, cutting, filing, drilling, bending, making simple lap joints and soldering.

(*iii*) *Elementary glass-work*—the ability to do simple glass-work is very valuable: cutting (sheet glass, tops off bottles, etc.), bending glass tube, drawing tube out to make pipettes, rounding tube and rod ends, joining glass tubing and making simple joints, as in T-pieces or Y-pieces.

All these activities are practical, though all have a theoretical basis, so the best advice to the teacher is to seek help from a specialist, to refer to suitable elementary guides (see Appendix C) and get as much practice as possible. In these tasks, as in so many others, the greatest enemy is the feeling of being unable to do it. The only cure is to try, and to keep on trying.

Work of this sort requires space and equipment. So far as space is concerned, a small work-bench in the laboratory or the preparation room is enough. If this is placed at right angles to a wall, both long sides are available for working. One side should carry a metal-working vice and the other a carpenter's vice. Some tools may be carried on racks at the outside end of the bench, the remainder on a wall-board rack. Tools may be carried in clips, in holes cut into the rack, or hung on nails. It is useful to draw the outline (or a black 'shadow') of each tool, on the rack. When the tool is removed the 'shadow' remains as evidence of what is missing. This facilitates the task of cleaning up and checking.

All tools should be kept in good condition by regular inspection and servicing. They should be lightly oiled when they are likely to be left unused for long periods, as during a school vacation.

Lists of suitable tools are to be found in Appendix D.

The organization of the laboratory

The organization of the laboratory, in terms of the disposition of its resources, equipment and apparatus should receive thought. As teachers usually find the laboratory already built, without having been able to contribute to its design, organization is often reduced to making the best possible use of the existing situation. Thus guidance may be offered only in very broad terms. The following points may be noted:

(*a*) Some kind of rational and functional organization is needed. Thus, according to circumstances, a teacher may choose one of two ways of disposing apparatus in common use:

(*i*) Sufficient of each item required is issued to a pupil, or group of pupils, and suitable storage space assigned.

(*ii*) The apparatus is stored in locations suited to the size and shape of the items, and is issued for use and immediate return as required.

Of these, (*i*) has the advantage of reducing time for distribution and recall, as well as that of providing an easy check on use, breakage, etc. At the same time it has disadvantages for stocktaking and may be rendered impossible due to an insufficient amount of storage space for large items (e.g. burettes, large jars, etc.).

(*b*) Whatever method is adopted, there should be:

(*i*) A precise record of all dispositions, kept in a central inventory or lab-log book.

(*ii*) Accurate, visible and legible labels showing contents of all drawers, boxes, cupboards, etc.

(*c*) In the disposition of apparatus questions of fragility and other aspects of security must be considered. Thus, if apparatus is issued as in (*a*) (*i*) above, the drawer or cupboard assigned should have partitions, to reduce the chance of damage to pipettes, etc.

(*d*) Dangerous materials (inflammable, poisonous, etc.) must be kept in a suitable location, under lock and key. (Issues to be made only under supervision.)

(*e*) Records should be kept to show rate of usage and date of re-ordering.

(*f*) All labelling should be accurate and legible. Etched glass is durable, but it does not permit of alternative usage and thus cannot be used for all the necessary labelling. If paper labels are used they should be written with Indian ink, fixed with a good glue and protected by a coat of varnish or a piece of transparent self-adhesive material.

(*g*) All drawers and cupboards should be labelled to indicate the contents. All locks should be numbered. Keys should be kept on a board, on which each location is numbered clearly.

An important aspect of laboratory work is the development of a suitable routine and the training of any laboratory staff. These are closely related, but the part played by pupils should not be overlooked.

Pupils should be trained to use the various pieces of apparatus, even the simplest, carefully and accurately. In setting up apparatus, in removing a stopper to pour from a bottle, even in carrying glassware, there are methods which minimize danger and are conducive to cleanliness and exactitude. Such methods should be demonstrated and demanded. Similarly, pupils should learn to avoid wastage of materials and to avoid dirt and untidiness. Even if there is adequate laboratory assistance, pupils should be expected to contribute to the cleanliness and orderliness of the laboratory in washing and replacing glassware, in disposing of waste and so on. Whether or not such procedures inculcate good habits, there is the immediate result that the laboratory is clean, tidy and sanitary. Wastage of materials and time is minimized. In some schools, where 'social service squads' are organized, some of the laboratory maintenance may be done by them. It is always desirable that those who use a laboratory should have responsibility for its maintenance.

Only in the larger schools, and not always then, is there an adequate service of laboratory-assistants. When they are available they range from the unskilled and unqualified labourer to one of last year's pupils with a 'school certificate', who has to earn a living. Whatever the kind of assistant available, the good teacher has to develop in his laboratory-assistant some kind of pride in his laboratory. How this is done is a test of the teacher's qualities of leadership. He must look for and help to develop special skills or interests and, wherever possible, pay tribute to these. There are many cases where, with encouragement and help, a laboratory-assistant has built up special apparatus, a special collection, etc., which has proved of very great help to science teaching.

Thus, within the school, the biologist should do everything possible to develop efficiency and enthusiasm in his junior colleagues. When possible, within a larger school system, the appropriate authority should arrange a special training course, for laboratory-assistants, in the various techniques demanded, in the using of simple hand tools, in maintenance of apparatus, equipment and furnishings.

Routine is extremely important as the basis of smooth-running laboratory organization. Attention should therefore be given to the following:

(*a*) The preparation of detailed plans for all *teaching work*. This plan should show, for the whole year, the work to be done for every period. In relation to each piece of work it should also show material to be purchased, collected, cultured or in any way prepared. These activities precede the teaching concerned. Both sets of dates must be known to the laboratory staff from the beginning of the year, because some activities may have to be initiated long before the relevant teaching is undertaken.

It is found convenient to prepare these plans in three ways:

(*i*) A broad plan for the year's work, with major activities noted. This should be on display in the laboratory as a guide to everyone.

(*ii*) A detailed plan, available to teachers concerned and to the laboratory staff.

(*iii*) An action plan containing only those dates on which previous action, of all kinds, has to be taken.

(*b*) A check list should be prepared of all required actions, distinguished between academic and laboratory staff. On a regular day of each week, this list should be checked over and initialled as a record that action has been taken and by whom.

(*c*) The best-laid plans go astray, especially in planning work which, the more biological it is, the more likely it is to be influenced by seasonal variation. The wise teacher, therefore, has alternative materials and plans to meet such contingencies. It is better to move forward in the work which is dependent only on the use of materials already available, such as working over histology slides, skeletal material or herbarium specimens. Such alternatives however have to be organized and ready. As they are consumed, others have to be prepared. The work originally postponed has to be fitted in. Careful planning is therefore essential.

(*d*) Outdoor work, such as field ecology or garden experimentation, requires planning. An essential item in such planning is experience. This however will not be available unless it is accumulated from year to year in a field notebook. Not only must a field notebook be kept, but it must be analysed and the key points tabulated and looked over as a matter of weekly routine. In this way it may, for example, be noted that the monsoon has set in much earlier than usual, and therefore a particular stage in a life history must be sought earlier than in more normal years. Such points tend to be overlooked unless routine examination of a check-list is carried out.

(*e*) Maintenance of laboratory furniture should be zealously performed against a check-list of duties, suitably timed and known to the laboratory-assistant.

(*f*) Maintenance of apparatus, such as microscopes, klinostats, auxanometers, etc. should also be undertaken against a set schedule. While the preparation of such a schedule is for convenience, it should be realized that continuous and frequent inspection is preferable to annual checking over. It may be made a practice to have pupils check their microscopes and report any necessary adjustment or cleaning once a month. Each vacation the check should be more exacting. A good teacher considers it an obligation to devote one or more days of each vacation to such work.

(*g*) Once a year there should be full-scale checking of the inventory. In addition to notes on shortages, consumption rates, etc., the 'condition' of each item should be noted on a special list. These items, such as adjustment of mechanisms, cleaning of lenses, should then be undertaken, for convenience during an examination or holiday period.

(*h*) While running repairs and maintenance should be undertaken continuously (e.g. oiling of locks, hinges, etc.), special attention should be given to such tasks in a school vacation. Furniture, especially laboratory benches, should be cleaned, waxed, varnished, etc. The maintenance of a high standard of condition and efficiency in a laboratory is not difficult, providing it is looked upon as an essential and continuous task carried out through a known routine.

Safety precautions should be noted carefully. It has already been pointed out that dangerous materials should be under lock and key and only issued with the proper precautions. The need to train pupils in a safe fixed routine has been noted. There must be a strict demand for attention to safety precautions, exhibition of safety notices, the provision of first-aid materials, checked regularly and immediately available and the development of proper precautions and training in their operation. These should include fire precautions and drill, dealing with acid burns, flame burns, cuts, electric shock and the mischance of poisoning. *In all this the teacher is the responsible agent.* He should know what to do, have authority to do it, have all the necessary information on display (accurate and up-to-date telephone numbers, addresses, etc.) and all keys should be available, in locations known to everyone and visible to all.

A problem which presents difficulty to the biology teacher is the provision of specimens. In some countries it is the practice to take public examinations which are under the control of outside agencies or examining syndicates in, for example, Cambridge or London. Whatever the position once was, it is now clear that such examining bodies make serious endeavours to reflect local conditions in their syllabuses and question papers. Though this has, to a large extent, done away with the artificial condition in which pupils know foreign species (e.g. the earthworm) from books, but do not know local organisms from actual specimens, it does not overcome the question of supplies.

In very few tropical countries have commercial biological supply houses been developed, and in the few which exist the standards of preservation and preparation still leave something to be desired. In the absence of such commercial suppliers, teachers are forced to call on whatever local sources exist (the fish market for example) or to buy from abroad. The former is largely a matter of chance; the latter is both expensive and often impracticable.

In such situations the significance of collecting, which can help to provide specimens, is obvious. Not everything can be collected easily, nor can a single school undertake to rear all the specimens it may need. A good deal of help is often obtained from the local botanical gardens, zoological gardens or university. Nevertheless, there still remains a real need for a well-organized supply of material.

CHAPTER VIII

TEXTBOOKS AND THE BIOLOGY LIBRARY

The biology textbook

In some places books have become almost the whole of education, and it is sometimes said that children know much about books and little about reality. There is some truth in this charge; but when it is followed by the demand that 'education should be less bookish' we must inquire into the use of books in education. We are here concerned only with one school subject, and must consider the question in relation to textbooks for class work and general books for free reading in biology.

It is extremely important for every teacher to think about the general problems of the textbook, its functions, characteristics and the methods of using it. Unfortunately these problems are too seldom considered, a textbook often being selected without regard to the factors which should be a guide. It must be admitted, of course, that choice, under some conditions, may be very limited; as, for example, where questions of the use of a national language arise, or in countries where secondary education is beginning to develop on a wide scale. These conditions, however, should challenge us to pay even greater attention to the problems involved. It is just here that opportunity arises to design and produce textbooks to fulfil the requirements which should be expected of them. Nor must it be forgotten that teachers do, and should, play a big part in the production of textbooks.

The function of the textbook

The function of the textbook is to provide, in readily accessible form, that body of knowledge which is required by the student in relation to a particular subject, in this case, biology. Now, as we have already seen, and as we know from experience, the work pupils can do changes with increasing age (and of course with differences of ability) in terms of amount and difficulty. It follows at once that if we attempt to write a textbook to cover the whole syllabus of a given subject, the study of which may take two, three, or even more, years, we must make allowance for changes in our pupils' ability to work. While it is true that many books have been written in a series of parts, becoming successively more difficult, it is also true that the need for this is equally often ignored. Thus, in one volume, written throughout at one level, we find the study material for several years' work. This is one of the most common defects in textbooks, and it often results in frustration, anxiety, and lack of interest among pupils who, too early in life, have been presented with work of too difficult a standard. Here then we have one guide in the task of selecting a text: that of ensuring that it not only covers the subject, but also takes into account the fact that, when the book is designed for use over several years, the earlier work must be treated more simply than the later.

Lines of approach in the textbook

Next we must consider the general attitude in the textbook as a whole. Biology is a subject which, however wide and diverse its various parts, can be reduced to a set of major principles, as discussed in Chapters II and IV. These principles are the real stuff of biology, and the pupil who does not understand them cannot understand the subject, however great his knowledge of details may be. The principles are based on details which, in this way, are put into groups and given meaning. An understanding of the principles of biology is not only important in the subject itself, but also in a consideration of the relations which exist between biology and other subjects. Especially is this so in regard to the applications of biology to social affairs. If we wish to ensure that biological education will affect the conduct of everyday life, in relation to hygiene, for example, our pupils must not merely memorize the life history of a parasite or germ-bearing organism, but must have a clear conception of the great principles, such as biogenesis, abiogenesis, antisepsis and so on. From principles we may derive knowledge and attitudes which act as a guide under widely varying circumstances. From details which are not drawn together into generalized concepts, we get a guide which has only a narrow reference to a particular situation.

Various studies of textbooks have shown that very many fail to demonstrate the major principles of biology, fail to show the dependence of principles upon details, and often include detailed material which makes no contribution to the building up of principles. Such books not only appear to be, but are in fact, overloaded with detail. There is so much specialist terminology that the pupil is overwhelmed and is likely to misunderstand. Such books fail to help the pupil to understand the principles of biology, and also fail to make any effective contribution to the important task of giving some understanding of scientific method. The very essence of scientific thinking is the ability to relate details to principles and to distinguish between the relevant and the irrelevant. This is a skill which is related to age and ability and, like all other intellectual skills, has to be fostered and exercised. Thus, we have a guiding factor in textbook selection: we choose those which demonstrate how the details of biology relate to, and are built up into, the major principles of the subject.

Textbook terminology

The matter of overloading has been mentioned. This is often seen in the unnecessary use of academic nomenclature and technical terminology. Biology, like every other form of knowledge, has its own terminology, in which every term has a narrowly defined and precise meaning. While this is essential, it must not be forgotten that it is also a mere convenience, a form of shorthand. When the scientist uses one of these terms, it brings to his mind knowledge gained from past experience, all summed up in a single word. When we present the pupil with the word he cannot clothe it with meaning; for him it is only a sound, and though he may remember it, it is likely to remain meaningless unless we give him the necessary experience.

The difficulties of terminology are made worse in two ways. Firstly, there are differences of usage among the experts themselves, and among those who write textbooks. Secondly, we find terms with multiple meanings, as well as various synonyms intended to convey a single meaning. These verbal difficulties have led to confusion and have resulted in a slowing down of scientific progress. The task of dealing with them however must be left to the scientists themselves. What the teacher must do is to avoid books with an unnecessarily heavy use of technical terms. He must use such terms as sparingly as possible, and ensure that when they are used pupils have the necessary knowledge and experience to understand and apply them. Both textbook writers and teachers too often behave as though a knowledge of terms must surely mean an understanding of biology.

The textbook and problem-situations

Biology, like all science, is a body of knowledge which has been built up because Man found himself confronted with problems. At first his answers to the problems were, despite their animistic, anthropomorphic and mystical nature, enough to quieten the uneasiness of not knowing. New knowledge, however, proved the old answers wrong, so the questions had to be faced again. The validity of successive answers increased as the apparatus of observation and criticism improved. If Man has learned through facing problem-situations, it would seem that the pupil of today should, at least to some extent, learn in the same way. Therefore, we should confront him with problem-situations. This is too seldom attempted by our textbooks, where we find descriptions, statements and answers to questions which have not been put. The pupil cannot himself ask these questions, because he lacks knowledge and experience. Hence we may derive two other guiding principles in regard to choice of textbooks. Firstly, we should attempt to select those which give attention to problem-setting situations. Secondly, we should choose those which stimulate interest and challenge effort, through which experience is gained.

Further desirable points in a textbook

Our pupils are faced with one problem which is usually overlooked: besides learning they have to acquire the skill of using a textbook efficiently. The art of reading effectively requires far more than the basic mechanical skill of reading, and is gained only slowly and through long experience. This complex and important art is much helped (and contributes more to the learning of the subject), when the textbook has certain characteristics of arrangement and organization. In this connection the following points should be noted:

(*a*) The basic plan of the book should be described in the introduction, and an analysis of contents should be provided. Some biology books are based upon systematic (taxonomic) principles; others are written around major themes in ecology, and so on. But, whatever method a book follows, material with a specific unity is likely to occur in several parts. This is confusing to the pupil, unless he knows the reasons for it. He can understand only when he appreciates the structural plan of the book.

(*b*) Full use should be made of the introduction and chapter and section headings related to each section of the book. This helps to build up a sense of continuity and wholeness, relates section to section and illustrates the interdependence of the whole.

(*c*) Full use should be made of cross-reference in the text and with regard to the illustrations. This leads to greater efficiency, by saving time and in emphasizing relationships.

(*d*) A good index is essential, not only to save time, but to encourage the habit of 'looking things up'.

(*e*) Tabulation of data, especially in comparative and analytical terms, saves space and aids understanding by providing an 'over-all' view and demonstrating interrelationships.

(*f*) A glossary of technical terms is valuable, especially if definitions are illustrated with roots, though these have little value, it must be said, when they depend on Latin and Greek, to pupils whose classical languages are Sanskrit, Pali, or Arabic, etc.

(*g*) A table of synonyms (various words for one idea) and of the multiple uses of a single term or word are a useful aid.

(*h*) Illustrations should be plentiful, clearly and completely labelled, and fully described.

(*i*) References to further reading should be provided.

The 'practical' textbook

Biology, like other sciences, is divided by custom into theoretical and practical work, though the distinction between theory and practice is largely a matter of convenience. While most, if not all, of the foregoing relates to 'practical' as much as to theoretical textbooks, it is necessary to give attention to a special feature of the former, or to what should be a special feature.

Much of the content of school biology is concerned with the study of structure, though there is a slow, welcome and necessary change towards more functional studies. In the study of structure, whether it relates to plants or animals, whether it is microscopic or macroscopic, the limited abilities of the pupil to think in three-dimensional terms results in difficulties. In most textbooks too little attention is given to this point and the pupil finds, even when there are sufficient illustrations, that he cannot translate two-dimensional pictures into three-dimensional concepts. There are two ways in which the producer of textbooks may help here.

(*a*) By using sectional diagrams cut in several planes, and not, as so often happens, showing, for example, only a transverse section of a plant stem or an earthworm. It should also be the practice to give sections at different levels, for example transverse sections of a worm at five or six different places, which should be located on a longitudinal section or diagram.

(*b*) By doing everything possible to create the illusion of solidity. While we rightly tend to ask pupils to make simple line drawings, there is no reason why, providing we retain clarity, we should not make use of shading and perspective and other devices to make an object look solid. A special case of this is the stereogram, which, if more frequently used, may be of great help to our pupils.

This same problem of three-dimensional perception arises in connection with dissections in zoology. The pupil who is dissecting a particular type for the first time is like a traveller seeking an unknown destination. Neither pupil nor traveller knows the way. A traveller asking the way to a temple would not be much helped if he were shown a picture of the temple. What he needs is information about the route he must follow, how to get from where he is to where he wants to be. A picture of his final destination is of far less help than a map or route-card. This is exactly the situation of the beginner with a new dissection to perform. In front of him is the skin of the animal, somewhere inside the skin are the structures he wants to see; but, instead of showing him how to get from one to the other, his practical textbook usually offers him a picture of what he is seeking to find.

In practical textbooks concerned with the learning of morphology by the process of dissection, illustrations should provide a stage-by-stage guide of what to do, how to do it, and of the order of procedure. For the simpler operations, simple line drawings are sufficient. Even complex operations can be dealt with by a series of line drawings. For complex operations it is necessary to have very detailed instructions. The dissection of the cranial nerves of the dogfish or skate, for example, involves a long sequence of operations. To illustrate them requires:

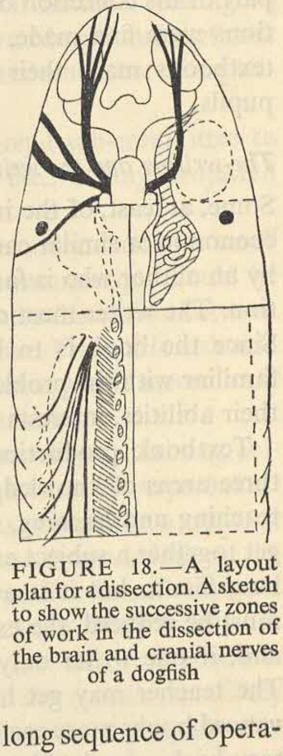

FIGURE 18.—A layout plan for a dissection. A sketch to show the successive zones of work in the dissection of the brain and cranial nerves of a dogfish

(*a*) A layout plan showing the successive zones of action. (See Fig. 18.)

(*b*) Stage-by-stage instructions for proceeding in each zone:

(i) the ophthalmic area
(ii) the orbital area
(iii) the spiracular area
(iv) the branchial area.

A set of illustrations of this sort may be based on line drawings, photographs, or both. Considerable time is needed in preparation, and the costs of reproduction are one of the reasons why such devices are not more widely used. Until more books based on such methods are available, it must be the teacher's responsibility to prepare such illustrative material himself, as part of his collection of visual aids. That is how many illustrations were first made, because dissatisfaction with inadequate textbooks made their production essential in order to help pupils.

The writing and the writers of textbooks

Some, at least, of the inadequacies of textbooks arise not from economic or similar causes, but because they have been written by an author who is familiar with only one aspect of the situation. The writer must obviously have command of his subject. Since the book is to be used for teaching, he must also be familiar with the problems of learning, that is, with pupils and their abilities, interests and limitations.

Textbook production, for school purposes, really involves three areas of knowledge, of the subject, of the psychology of teaching and learning, and of the problems of school life. To get together a subject expert, a psychologist and a teacher may be difficult, but it is an ideal to be remembered. If the field must be reduced, the expert and the teacher might co-operate; and, if one writer only is involved, it should be the teacher. The teacher may get his facts from the expert and from advanced books more easily than the expert can acquire the necessary background of knowledge of schools and pupils.

In many countries the need for textbooks for secondary school work is among the most urgent needs of education. To produce biology textbooks, which possess the qualities considered desirable, and described so briefly here, requires careful planning. Experience over the past few years has shown that, if left to chance, production will be inadequate.

To enter into discussion of the administrative, economic and other problems involved is outside the scope of this book. But one general suggestion may be made. A textbook committee could be set up in any suitable region, and divided into subcommittees based on subjects. These might be further divided in terms of age of pupil, type of school, etc. Each of the sectional sub-committees so formed, for example that on secondary school biology, should include a subject expert, an administrative official, a publisher (to advise on technical matters relating to book production in general), a lecturer on educational methods (from a university or training college), and a number of experienced teachers.

It should be the task of such a sectional sub-committee to plan the general layout, content, size, etc., of any projected textbook.

The writing of the textbook should be undertaken by a small team or a suitable individual. The first manuscript should be regarded as a draft, to be used as a basis for discussion between the writers and the sectional sub-committee. From this it should be possible to arrive at a final manuscript which meets local needs and provides for teachers' requirements.

In some countries, some of the teachers in the training colleges and university departments of education are experienced men and women who have returned to college for a year or more of study. Among them are biologists. It would lighten the task and speed the process of textbook production, if this pool of potential skill and experience could be used. While it may not be possible for them to help in writing the text, such students may prove useful as critical readers of the manuscript. They may help in the preparation of diagrams, in carrying out dissections and other practical work, from which diagrams and photographs may be made, and in the production of tables, appendixes and index. And, in a country where several language versions are needed, they may well help with the tasks of translating.

Are textbooks necessary?

Some teachers believe that textbooks are not essential, provided that certain conditions are fulfilled: the teacher must be an expert in the subject, there must be an adequate reference library, there must be an efficient service for the duplication of specially prepared notes—and the teacher must be particularly enthusiastic and hard-working. In such a situation the usual textbook may be replaced by duplicated sheets, prepared by the teacher and issued to pupils as occasion demands. The advantages of such a system are said to be:

(*a*) The material content may be closely related to local needs and problems.

(*b*) Greater interest is aroused because the system appears to be more personal to the pupil.

(*c*) Pupils may incorporate their own materials, such as experimental results, illustrations and extra notes, thus further stimulating interest and effort.

(*d*) Costs are reduced, and the class is freed from the difficulties of shortage, or of books being out of print, and the like.

Whether or not this system is ideal, each teacher must make his own decision. It is, at any rate, a system which may be operated at once in places where commercial productions are not yet available. Moreover, it is undoubtedly an excellent first step in the production of a suitable textbook, because the material may be tried out in class, modified by experience, and thoroughly tested before it goes into print.

Which textbooks?

In this book it is impossible to recommend textbooks by particular writers, or for particular countries. There are, however, two suggestions for those about to take up the teaching of biology, or those with the task of introducing it as a new subject to a particular school.

(*a*) Before making a choice, as many as possible should be examined, not only to see the range available, but to obtain some idea of standards of book production. It is even worth while to purchase a few which, because of their origin, are unsuited to local conditions, provided they illustrate some of the desirable features of the good biology book. In Appendix G there are annoted details of certain books, which, although written for use in North America or Europe, are of particular interest. To examine them may help teachers to understand how to look for desirable features in textbooks and guides.

(*b*) It should be noted that, although convenience and custom may have led to the adoption of a single textbook in any one class, it is not essential to follow this fashion. Books vary in the attention given to particular points, in their lines of approach, arrangement, and so on. No book is likely to contain all the desirable features. Thus it is often an advantage to have two or three textbooks in use. This does not mean that copies of each must be supplied to every pupil, thus adding to costs. The class may be divided into sections, according to the number of different books it is proposed to use, say three. Each pupil in a section has a copy of one book. Then the class works in groups of three, one from each section, so that every pupil derives help from each book.

The school biology library

A library is essential for the teaching of biology. The most important reasons are:

(*a*) Problems and difficulties, which cannot be solved by the help of the usual textbook, arise, especially in more advanced work.

(*b*) No teacher is an infallible guide, so reference to books other than those used in class is sometimes required.

(*c*) Pupils working at advanced level have to read reference books.

(*d*) Biology is a subject often arousing interests both wide and deep, which may lie outside the syllabus, and may involve collecting, aquarium work, etc. Such interests should be fostered by the provision of books on the techniques involved, on identification, and so on.

(*e*) If the relations of biology with other fields of learning, and with social affairs, are to be shown and explored as they should be, library resources are necessary.

(*f*) Provision of a library, by making wider reading possible, contributes to wider interest and deeper understanding of biology.

(*g*) A library shows that there are differences of viewpoint, and how scientific knowledge has advanced through the development of hypotheses, successively more exact. In this way it contributes to the development of scientific attitudes.

(*h*) A library encourages the reading habit, which not only opens new worlds to the individual, but also helps social progress by fostering the development of the individual.

The location of the books

Though it may be desirable, it is not essential to have an extensive library. Much may be done to provide services of the kinds already suggested, with only a few shelves of books in class-room or laboratory. Where a larger collection is possible, the question of location at once arises: shall the books be kept in the biological department or in a centralized school library? Each has its special advantages. Most frequently, when it is desired to look up something, for example, a point in technique or a case of identification, the need arises suddenly and in connection with a job in hand. It seems desirable, therefore, to keep a selection of books (for 'quick reference') in the laboratory. But many books, for example Darwin's *Origin of Species*, have considerable interest and educational value for students outside the specialist group. Moreover, a bound collection of lectures may contain some of particular interest to the biology student and some dealing with different subjects and of greater importance to other students. It may be claimed that a centralized system provides more efficient administration, and that the books suffer less damage. Local conditions must be taken into account when a decision is to be made. The choice should depend on pupils' needs rather than any other factors.

In some schools it may be possible to buy duplicate copies of the standard biological books. One copy may then be kept in the biology department and the other in the school library. When funds do not permit this, the books (that is, single copies) may be obtained for the library in the usual way and then issued on permanent loan to the laboratory, where they are kept. Such permanent loans should be limited to essential reference books, in order that the usefulness of the central library may be maintained.

Book selection and purchase

(*a*) The *economics* of most school libraries is a difficult problem and, where no library grant is available, the teacher must do the best he can. Here are some possible ways of collecting funds and books:

(*i*) The holding of displays of work, or an exhibition; the organization of 'jumble sales' (sales of odds and ends given for the purpose by parents and well-wishers); and seeking voluntary contributions as widely as possible.

(*ii*) Encouraging school leavers, individually or by classes, to contribute gifts to be used in helping the study of their favourite subjects. A suitable book-plate should be designed, with, for example, the statement 'presented by G. Smith of Form V, 196–', etc.

(*iii*) Encouraging those who own suitable biology books to lend them to the departmental library. The teacher should join in the scheme.

(*iv*) Doing everything possible to arouse interest in the library on the part of parents, well-wishers, Government departments, Missions, Trading firms, Information offices, etc.

(*b*) The *sources* of purchase also require thought. The teacher should:

(*i*) Collect and file all available catalogues from publishers.

(*ii*) Obtain catalogues from the more reliable dealers in second-hand books.

(*iii*) Read the reviews, which appear in many periodicals, of newly published books.

(*c*) The *kind* of purchase must be based on the important principle that selection is better than collection. What is needed is a representative collection, based on careful selection in relation to needs. It is obviously impossible here to make detailed suggestions to meet the needs of many diverse situations. It is clear that the biology section of the library should contain:

(*i*) Books on techniques, such as microscopy, collecting, taxidermy, etc.
(*ii*) Manuals for identification of plants and animals—in so far as they are available.
(*iii*) Guides to aquarium and vivarium methods.
(*iv*) Studies of special problems: evolution, parasitism, distribution, ecology, etc.
(*v*) Studies of special groups of animals, the vertebrates, the mammals, the invertebrate groups, etc., and similarly for special groups of plants.
(*vi*) Descriptions of biological travel and adventure.
(*vii*) Lives of some of the great biologists.
(*viii*) Books on local biology.
(*ix*) One or two natural history magazines.
(*x*) Guides to the local museum, etc.
(*xi*) Government reports with a bearing on local biological problems.
(*xii*) A standard encyclopaedia of natural history.
(*xiii*) Textbooks.

Despite the increase of writing in many national languages, it still remains true that books on biological topics (and many others) are more easily obtained in European languages, especially English. This is one of the problems which have to be faced in the development of secondary education outside the areas where European languages are used. As there is also a shortage of biological experts in these regions, the preparation of books, especially for educational purposes, must, in its early stages at least, be dependent upon translation. This however is unavoidably slow and teachers should try to keep up to date by reading advertisements, book catalogues and reviews.

Attention should also be paid to the various 'cheap editions' and low-priced series of books, of authoritative standing, now available. These are so numerous that much of a small library may be built up on them. In Appendix E a number of selected titles are given from a few of the better known series of this kind.

Classification and cataloguing

Classification. This word means 'the grouping of things together according to their degrees of likeness'. We try to use the method of grouping best suited to our particular purpose. For example, a trader may classify eggs according to size, and rags by the kind of fabric; and a scientist may classify substances as elements and compounds, plants by the types of flower, animals according to their structure; and so on. When we are dealing with books, the *subject* is the most important factor, and on subject-matter we base our classification.

There are several systems of library classification. While it may not be necessary to use any one of them, the teacher should be aware of them because he may, with a little knowledge, decide that one or other has advantages over an *ad hoc* method of his own. Before making his choice, however, he should find out what system is in use at any neighbouring libraries. Co-ordination is helpful to students who may use more than one library. Anyone starting or developing a school library may also benefit greatly by the advice and guidance of an experienced librarian.

One common system is shown here:

Dewey's main classes

000 General Works
100 Philosophy
200 Religion
300 Sociology
400 Philology
500 Science
600 Useful Arts
700 Fine Arts
800 Literature
900 History and Travel

Each of these main groups is divided into ten divisions, which can be seen by considering main group 500, Science:

Sub-groups of class 500, Natural Science:
510 Mathematics
520 Astronomy

530 Physics
540 Chemistry
550 Geology
560 Palaeontology
570 Biology
580 Botany
590 Zoology

Each of these ten groups is further sub-divided as follows:

570. Biology
571 Prehistoric archaeology
572 Ethnology, anthropology
573 Natural history of Man
574 Natural history
575 Evolution, phylogeny
576 Origin and beginning of life
577 Properties of living matter
578 Microscopy
579 Collector's manuals

By continuation of the decimal convention each of these divisions can be further sub-divided, as shown in the following example:

575. Evolution, phylogeny
575·1 Heredity. Eugenics
575·2 Variation
575·3 Ecology. Environment bionomics
575·4 Adaptation adjustment
575·5 Sexual selection
575·6 Development
575·7 Degeneration. Regeneration. Extinction
575·8 Origin of species
575·9 Origin of sexes

This series, represented by first-place decimals, still covers subjects of very wide range, so that it is necessary to sub-divide them again, each into nine. Thus 575·1 (Heredity. Genetics) is itself further divided into 575·11, 575·12, etc., in this way breaking down Heredity and Genetics into sub-divisions. Even these remain large. Thus still smaller sub-divisions are used, but it is not necessary to go further in an elementary survey of the method.

This procedure, however elaborate it may appear, is not difficult to understand or operate. That it is widely used is evidence of its convenience and efficiency. Indeed, so much is it used that many books are published bearing their Dewey classification number. As so many of the large Public Libraries and libraries of the State Education Departments use Dewey's method, it will be found useful to adopt it for school purposes, even for a small collection.

It must, however, be noted that other systems exist, such as those of Bliss, Brown and Ranganathan, and each has its special advantages.

The important point is that every school should have an efficient library service. On this depends the potential value of the library as well as its preservation, and one aspect of efficiency is complete and standardized cataloguing. There are many teachers who would agree with this, but be unwilling to make use of anything beyond a 'simple' catalogue, such as giving to every book a class letter and a number. It is true that such 'simple' systems can be made to work, but they give no real training in the use that can be made of major libraries after leaving school. Such teachers do less than they should to help pupils towards an important skill: that of finding information. *Classifying* is an important aspect of library work and consists of deciding into what position in the catalogue a particular book will fall. This is not always a simple task and, even within the framework of the Dewey system, it is possible for librarians to give different positions to the same book. Among the factors to be taken into account, the major contents are the most important. This subject, however, can only be dealt with here in a few brief remarks.

In a school library, especially a sectional library, some latitude in classification is possible, because the number of books is small enough to be looked over when a particular book is sought.

Nevertheless it may be useful to have a coding system where each book has a coloured disc on its spine. Thus red may be used for vertebrates, blue for invertebrates, green for general works. All zoological books may have a black disc, all botanical books a white one. A system of this kind gives visual help in replacing and selecting books, and the fact that some books carry more than one colour helps to demonstrate systematic and logical relationships.

Where funds allow, duplicate copies may be purchased, not only to meet the demand for a popular book, but also to allow one book to occupy two places.

Where duplicates cannot be purchased, or when it is not considered necessary to do so, one book may be represented by more than one card in the card-index. This again helps to emphasize the divisions and interrelationships of the field of biological knowledge.

Library work demands various skills, but training in librarianship is not essential, however desirable it may be. For small-scale work the needs are: good organization, a sound method of classifying, a complete catalogue, and a fool-proof loan system.

In a school perhaps the best arrangement may be based on the principles of systematics (taxonomy). Pupils should have some knowledge of this, and the scheme helps them to understand how the books are arranged, and at the same time extends their knowledge of systematics.

Each book must be classified so that it has an appropriate place, and should carry a 'press mark' for identification and cataloguing.

Press marks are used to indicate ownership and the serial number, or accession number of the book; they begin at 1 and are a serial record so that the last book purchased has the highest number, and thus shows the total number of books owned at that time. They are usually stamped on the title-page and at one or two other places, often on the back of the plates. Embossed press marks have the advantage that they cannot be erased.

Using the library

Reference or loan? It must be decided whether the biology library is to be used only for reference purposes or whether it is also to provide a loan service. The former reduces losses, reduces wear and accidental damage, requires less administration, but may need more supervision. A loan service, despite increased loss, damage and clerical work, is potentially more useful to pupils. There is seldom enough time for library work during school hours, and this is compensated for if a book can be taken away. In a boarding-school it is possible to provide plenty of opportunity by having the library open after normal teaching hours, but this does not help the day-pupil. Moreover, books are often required for use outside the library, for purposes such as the dissection of an unusual specimen by a particular and detailed method. A task of this kind may necessitate the use of a book for a lengthy period, as, for instance, in the identification of specimens. On the whole it would appear best to have certain books restricted to library reference (such as large encyclopaedias) while all others are available for short-term loan.

Availability. The main aim should be to have the library service available as much as possible. If the biology library is actually in the biology department, immediate reference is possible the moment need arises. The loan section should be open as often as possible, though it may be inconvenient to have it open during actual class periods as this upsets normal class-room routine. Before and after school, and during breaks or recesses and lunch time (midday dinner hour), are all possible times. The extent to which they are used must be decided by the time which can be devoted to supervision.

Supervision. While it is usual for a member of the staff to act as librarian, and though it is both desirable and necessary that the biology teacher should be closely associated with his departmental library, there are two or three reasons why the help of pupils should also be sought. Firstly, this reduces the call on staff time and effort. Secondly, it is one of the ways in which the school can fulfil its responsibilities in regard to social development. To accept responsibility is a capacity which has to be learned by the individual, just like any other skill. Thirdly, the position of library helper may be a help to a pupil weak in biology. The use of the classification system, the need to use terminology, and so on, help him to extend his knowledge. Fourthly, the dignity of a responsible position often 'sobers up' a pupil of high spirits who needs more to do. Valuable work of this kind should never be used as a punishment.

Loans. When a *reference book* is taken from its shelf, it is, in effect, on loan, and may be 'out' and in use either for a few minutes or even for a whole day. Moreover, it may be in use in the library, class-room, museum, school garden, or elsewhere. It is therefore wise to have a system for recording all reference books which are taken away from the library, so that they can be called in when needed for some urgent purpose. A convenient way of doing this is to enter a record in a suitable book, or on a card, and also to place a sheet of card or board in the place from which the book has gone. Each pupil in the sixth form of pre-university level may be provided with two or three such cards which carry his name and form. In the form below only two cards, and in the next form only one card should be allowed. Whether more junior boys should be allowed to remove books from a reference section is debatable, but it is highly desirable that they should be encouraged to use it, or to do some of their work in the library. The cards or 'formers' not only mark the vacant places in the shelves, but act as a receipt for the book taken. The other record is entered in a book or on a card as suggested. The use of cards of say 8 by 6 inches may be recommended. Every book in the reference section is represented by a card. At the top are the bibliographic data, author, title, press mark, and shelf location. Below are columns for names and dates. The borrower finds the card corresponding to the book he proposes to remove from the library for a length of time within the permissible limits (e.g. all day, one day, overnight, etc.), signs it and enters the date. He takes the book and replaces it with his personal card and, on returning the book, gets the supervisor's signature, puts back the book and retrieves his personal card.

The cards representing the books can be filed in a wooden tray of suitable dimensions. They may be arranged either alphabetically by authors or on the systematic or other plan used for cataloguing and arranging the books on the shelves.

For the *loan section*, loans should be recorded in a book or file. As this will probably contain many more books than the reference section, it is inconvenient to have a card box. Instead there may be a file of cards for each pupil, on which is shown the books he has out, the date taken, and the date returned. Most frequently, however, use is made of a book recording the borrower's name, the title of the book, and the dates concerned.

Efficient records of loans are essential and should be accompanied by a regular check once each month or term and an annual stock-taking.

Library regulations. These should be as few and as simple as possible. The duration of a loan must be defined, for example, a maximum of one week. Hours of opening must be defined. To prevent damage, tracing or other copying should be allowed only in the library, and writing in, or marking of, books must of course be forbidden. Losses and damage should be reported at once. Library books found lying about the school should be taken to the librarian.

A teacher's library

The divorce between theory and practice in education is to some extent the result of conditions in which the teacher seldom comes into contact with theoretical problems, once his training is complete, and there are few means by which he may do so. A library for teachers is one way of trying to overcome this difficulty. Such a library may be a centralized service in the school office or staff room, or be of sectional type located in the appropriate school departments. In connection with the teaching of biology, many books are available from which to choose a small number to act as a guide. A list of these is given in Appendix F.

The protection of books

Books have to be protected from loss, wear and tear and the effects of climate and pests. Loss is counteracted by efficiency of cataloguing, checking, and loan recording. Wear and tear demands mechanical procedures, while climate and insects must be dealt with in other ways.

Wear and tear may be reduced in three ways:

(*a*) By expecting, demanding and insisting on fair usage, protection of books from rain, etc., prevention of defacement, etc., by the borrowers.

(*b*) By preparing books for library service wherever it appears desirable, e.g. paper-backed books may be provided with stiff covers.

(*c*) By effecting repairs at once where there is evidence of wear. Thus loose pages and plates should be carefully re-inserted and loose bindings repaired. Book craftsmanship is a special branch of the librarian's work, and many teachers not only profess to know nothing of it, but believe that it is too complex for them to attempt. This is not justifiable in any way and any teacher can learn enough to do simple repairs, or to show his pupils how to do them, by the simple process of taking an old book to pieces and noting how it was put together.

Climatic conditions and the ravages of insects, fungi and other agents are serious troubles in library work, especially in tropical conditions. Unless preventive action is taken they lead to the early disfigurement and loss of books.

So far as climate is concerned, steps should be taken to do two things:

(*a*) To provide adequate ventilation, ensuring that still air and high humidity do not affect the binding and glue nor encourage the growth of fungal spores. If open shelves are used the cupboards should have wire network, or expanded metal doors. If ordinary doors have to be used they must be opened every day, and the books should be taken out and ventilated frequently.

(*b*) To ensure that books are not stored, or even left for a short time, in direct sunlight, which causes warping and fading. The effect of insects and other pests is reduced by adequate ventilation. It is advisable, however,

(*i*) To keep naphtha or camphor-balls in small boxes on each shelf.

(*ii*) To brush and shake each book at regular intervals, especially to keep clean the space between the spine cover and the back of the sewn pages.

(*iii*) Varnish the covers with a protective paint or solution which may be obtained commercially or made in the laboratory. A suitable recipe consists of 502 mercuric chloride and 502 phenol dissolved in 2 gallons of industrial spirit.

(*iv*) Any book suspected of having mites, etc., inside the spine, or bored into by bookworm, etc., must be treated at once. A convenient way is to keep such books for 24 or 48 hours in an air-tight box containing an open jar of crystals of paradichlorbenzene, a poison to be handled with care.

(*v*) The woodwork of shelves should be washed with hot soap and water and painted over with a dilute disinfectant.

(*vi*) The customary precautions should be observed against termites, e.g. by standing the legs of the shelves in trays of water with a layer of kerosene (paraffin) on top.

(*vii*) Powdered borax and DDT powder should be dusted on all shelves.

CHAPTER IX

VISUAL APPROACH TO THE TEACHING OF BIOLOGY

In recent years there has been greatly increased interest in the use of visual aids in education, particularly in the teaching of biology. Before accepting what has today become a fashion in education, some critical thought should be given to a number of questions.

What is meant by a 'visual approach'?

The materials of education are of many kinds and they range from all kinds of apparatus to abstract ideas on the one hand, and from direct to indirect (or vicarious) experience on the other. We need knowledge of these raw materials, which are also the vehicles of education, and skill in handling them. In the past we have tended to be mostly concerned with information and attainment, assessed and tested by verbal and written means. From this has come the very real danger that we may give more attention to remembering than to experiencing or understanding. How real this danger is can be seen by examining the textbooks used in schools. They are often so lacking in illustrations that pupils are expected to read and learn about things of which they can form no visual concept at all.

In an attempt to remedy the trouble we now give far more attention to the use of visual materials. This development is of comparatively recent date, but is by no means a new idea. Man's earliest sign-writing was probably intended to be representational, attempting to convey an idea by drawing an object. In times of antiquity men made pictures or carved images in rock for the same purpose. Thus today we are turning back to what has always been accepted, but neglected as a result of our concern with remembering rather than with feeling or understanding: that learning needs a firm basis of reality. To appreciate the situation in simpler terms, we may imagine a boy who lives in a great city learning about life in a foreign village. His own direct experience is metropolitan. He may have some knowledge, direct or indirect, of the villages of his own country, but is this a guide to understanding what it is like to live in a jungle or a desert? If the scene is described to him he will form some kind of mental image, but his imagery has to be based on his own experiences, and these are likely to be misleading. The value of visual materials in such a situation is obvious. Has it not been reported that a Chinese philosopher once wrote 'one picture is worth a thousand words'?

The visual approach, however, means far more than the mere showing of pictures. This is important, but it is only the beginning. To use visual methods to the best advantage means understanding the potential values of the method. This chapter is written to help the teacher to gain this understanding. It is concerned first with the basic theory of the visual approach, and then with the application of this to the practical class-room situation.

The available visual aids

Visual aids range from 'the things themselves' (such as fossils, bones, plants and other specimens) to representations of them (such as photographs, pictures, diagrams). In addition, they include apparatus and machines to enable us to make use of these materials. These two groups, materials and machines, are closely related to each other, but for convenience they are considered separately.

Visual materials

(1) *Real objects*, such as specimens of all kinds, fossils, microscopic slides, and so on, are visual aids to learning. To make full and effective use of them is difficult. Some things are too large to be brought to the class-room, others are rare and costly, some may not be available when we want to use them. At the same time, some teachers do not make enough use of the materials that may be readily obtained. How often does a pupil copy a picture from a book, or a blackboard diagram,

instead of looking at something as common and readily available as a flower?

One of the teacher's first tasks is to ensure that real objects are used as fully as possible.

Every teacher of biology should make it his aim to have an adequate supply of biological materials. Among these the following should receive special attention:

(*a*) *Microscopic slides* to illustrate microscopic structures of all kinds. A limiting factor may be the cost, but this can often be reduced by various means.

(*b*) *Skeletal materials*, such as a few large skulls (dog, goat, sheep, rabbit, crow, etc.), the complete skeleton of a rabbit, a dog, a frog, a lizard, etc., and sets of limb-bones, etc.

(*c*) *Plant specimens*, prepared and mounted on herbarium sheets, and arranged in two sets. Of these one should be in terms of systematic (taxonomic) relations, the other in ecological terms (different kinds of habitat).

(*d*) *Animal specimens*, in spirit, stuffed and mounted, dried, etc., according to the type of material.

These materials must be used and handled by the class so that familiarity gives a background for understanding. Such a collection should ignore the limits of the syllabus. To get an understanding of the vertebrates, for example, a pupil needs to see far more than a frog and a rabbit.

A collection of suitable materials is perhaps best arranged as part of a museum connected with the biological department of the school. Some of the problems which arise are dealt with in Chapter X.

(2) *Representational materials* are often required owing to difficulties due to size, cost, rarity, etc. The teacher and his pupils should collaborate in building up a suitable supply. This includes:

(*a*) *Pictures*. From the firms which supply biological teaching materials it is possible to buy large wall pictures. From big museums, zoological and botanical gardens, picture postcards are available. Many pictures of potential value to the teacher are to be found in illustrated magazines. A large collection of these may be made.

(*b*) *Photographs.* If cost does not prevent it, photography is of great service to the biology teacher. He can use it to make serial records of growth, unusual phenomena, special habitats, and so on.

(*c*) *Diagrams.* Specially prepared diagrams are an essential aid to the teaching of biology. Some are available in textbooks and others may be purchased from commercial sources. There is no reason, however, why they should not be prepared by the teacher and his pupils for their own use.

(*d*) *Models* are of particular value to the biologist because they possess a three-dimensional quality absent in pictures, photographs or diagrams, except where an illusion of solidity is sought in the stereogram. Moreover, a model may be handled by the pupil, who gains from it because the sense of touch is another means of learning. Further, we can make enlarged models of what is very small in nature. It may be useful to classify models into three kinds:

(*i*) *Scale models,* which reflect very exactly the structure of the original, but on enlarged or reduced scales.

(*ii*) '*Free-lance*' *models,* which are not to an exact scale, but which are sufficiently like the original to be an aid to learning.

(*iii*) *Analytical models,* which are in no way representational of real structure, but illustrate how a particular structure works, e.g. a muscle and joint model.

It should be noted that all the materials in the above list are *static.* Other models may be made to move, or appear to, but pictures, photographs, specimens, etc. are all still. It may also be noted that, with the exception of microscopic-slide preparations, all these materials may be examined without the aid of optical devices such as microscopes and projectors. When we turn to visual materials needing optical apparatus, we become concerned with the machines used in visual education.

Apparatus

(1) The '*magic lantern*' or *projection lantern* is an optical device by which an enlarged image is projected from a small transparent slide. The apparatus consists of a lamp house containing the lamp, a condenser to condense the rays of light, a slide carrier to hold the lantern slide and a lens to form the image. These components are arranged on a base-board and there is provision to alter their distance from each other, thus ensuring: firstly, that the slide is equally illuminated all over at the maximum degree of brightness; and secondly, that the projected image is in sharp focus.

The *optical principles* mean that the image is reversed both from top to bottom and from left to right. Slides, therefore, must be put in the carrier upside down and reversed from left to right. To ensure this slides are 'spotted' with two white spots.

The slides usually consist of a photographic positive printed on a glass plate, carrying a gelatine layer incorporating the photographic materials. To provide protection the sensitive surface is covered with a sheet of glass, and the two glass plates are bound together by tape round the edges. Slides are of various sizes.

3¼ inches by 3¼ inches is the English standard size.
4¼ inches by 3¼ inches is frequently used in the U.S.A.
6 cm. by 9 cm. is usually used in Europe.
50 mm. by 50 mm. is the international standard used for the miniature slide projector.

Although most slides are made by a photographic process, it is possible to make them by other means, particularly in the case of diagrams, textbook material and tabulated data. The following hints are useful:

(*a*) Take a clean glass slide of appropriate size and write or draw on it with wax-pencil or glass-ink (both of which are obtainable from visual-aid dealers).

(*b*) Take a spoiled or unwanted photographic plate and bleach out the image, wash and dry and then write or draw on the clear gelatine with Indian ink.

(*c*) Cut a piece of cellophane (a transparent plastic) to appropriate size, place it between a folded sheet of carbon copying paper so that it is in contact with the carbon surface on both sides. Draw, write or type what is desired; this will be copied on the cellophane, which must be mounted between glass slides to protect it.

(*d*) Take a clean glass plate and smoke it black, or paint it with lamp-black or even paint until opaque. Use a needle or other sharp point to draw or write on it. For protection either varnish the surface or use a cover glass.

The first two of these methods are particularly useful, because it is often possible to trace a textbook diagram by their aid.

(2) *The miniature projector* is of special interest because it may be used in various ways, and may be cheaper than the standard lantern. Like this apparatus, it is a diascope, because the rays of light pass through a transparency. The slide used, as already noted above, is 50 mm. square. The smaller size means it is cheaper, takes up less space, and is less likely to be dropped or broken.

The most valuable feature of the miniature projector, however, is related to the use of *film-strips*. A film-strip is a series of pictures, diagrams, textual matter, etc., printed on a length of cinema film. One strip, dealing with a particular subject, and with its content edited by experts, may have as many as forty or fifty pictures or 'frames'. As it rolls into a cylinder only about 1½ by 1½ inches, the saving in bulk is considerable, an important point in storage. Moreover, it does not crack, if dropped. It resists wear, when used with care, and is far cheaper than an equal number of glass slides. Also, there is a wide commercial production of educational film-strips, and biological subjects are readily available. In most cases the strip is accompanied by a brief set of notes describing each frame in detail. These give a general review of the subject, and offer comments on how to use the strip in teaching.

There are three sizes of frame used in film-strip making, all based on perforated cine-film, which is 35 mm. wide. The largest, 36 by 24 mm., is the standard 'British frame' based on the camera negative size first adopted by the Leitz Leica camera, and now almost universally used. The next, 24 by 18 mm., is the 'half-frame', the size of the commercial film-strip producers. The third, 24 by 24 mm., is the square format used in Robot and similar cameras, but seldom used for commercial film-strip work.

In purchasing a miniature projector the following points should be carefully noted:

(*a*) *Illumination* is usually by electric current, using either A.C. or D.C. current. Lamps are designed to operate at a particular voltage, such as 220, 110, 12 or 6 volts. It is essential to use either the right current directly, or to use a transformer or rectifier.

Mains current should be used, where available, with lamps of 100, 200 or 300 watts, according to the size of the room where the projector is employed.

A 12- or 6-volt car battery may be used with a suitable 60-watt car headlamp bulb when no mains current is available, and where the battery can be recharged.

(*b*) *Cooling*. High-wattage lamps and incandescent mantles generate considerable heat. It is essential to be sure that the lamp house is adequately ventilated. Make sure by trial, not merely by inspection or by taking the dealer's word for it.

(*c*) *Sturdy constitution.* It is better to buy a machine made of die-castings, with all threaded rings cut in solid drawn tube or castings, rather than one based on sheet metal and pressings.

(*d*) *Simplicity* is a valuable feature and the beginner should avoid a machine with too many gadgets.

(*e*) *Versatility*. A good miniature projector has a rotating head, to allow the use of both vertical and horizontal pictures, a set of masks to allow the use of full and half-frame sizes, easily interchanged carriers for allowing the use of either miniature slides or film-strips, and a device permitting the use of interchangeable lenses of different focal lengths, and, sometimes, a microscope objective to project micro-slides.

In a school which has no projection apparatus at all, but where it is proposed to start the use of such visual aids, a good miniature projector is perhaps the most suitable first purchase.

It is cheaper than an equally well-built new standard projector, more versatile, and can be used in daylight, or in semi-darkness (unlike the episcope).

(3) *The episcope or opaque projector* projects an image of a picture or small object by the use of reflected light. Because of this the effective illumination is less than in the diascope, where transmitted light is used.

The *optical principles* involve a mirror, which overcomes the inversion effect caused by the lens, so far as lateral inversion (right to left) is concerned. The image is made to appear the right way up by putting the picture in appropriately.

The advantages of the episcope lie in three features, all of very great value to the teacher of biology:

(*a*) The original material, of which the image is to be projected, does not have to be made by a special photographic process. Pictures in books, picture postcards, diagrams, etc., may be slipped into place at once.

(*b*) The image reflects the natural colours of the original.

(*c*) The original need not be a flat picture. Small solid objects, such as a bone, a bas-relief model, etc., may be used, though the optical problems may make it impossible to have all levels in sharp focus simultaneously.

The disadvantage of the episcope lies in the fact that, because it uses reflected light, the illuminant must be of high power and projection must be carried out in a dark, or nearly dark room, and electric current is needed for most commercial models.

The episcope is obviously a very useful machine and its major defects can be overcome, to some extent, in two ways: either by using very high-power lamps (e.g. 1,000 watts, or a very high candle-power incandescent mantle lamp) or by modifying its design and method of use. The former involves very considerable expense, while the latter requires some skill and ingenuity.

In the latter case a mirrorless episcope is used in conjunction with a translucent screen. The principle is shown in Fig. 19. Light from the lamps falls on the picture at P and an image of this is formed by the lens at S. By putting the picture in position upside down the image at S is upright. As there is lateral inversion, but no mirror to correct it, the image at S is viewed from the far side of the translucent screen when it will be seen as laterally correct. Under this condition of viewing, the image appears brighter than is usual with an episcope, because reflected light is used at P and this beam is seen through the translucent screen.

In buying an episcope, attention should be given to:

(*a*) Sturdy construction.

(*b*) Efficient illumination.

(*c*) A picture area as large as possible.

(*d*) Ease of dismantling and cleaning.

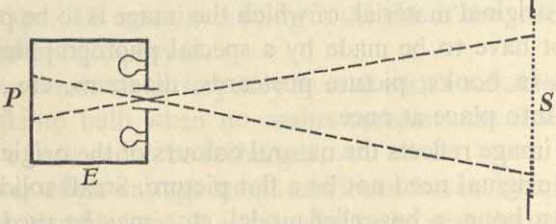

FIGURE 19.—Rear projection with an episcope. E is an episcope without a mirror. The picture is placed (upside down) at P and is viewed from the far side of the translucent screen, S

Three ways in which a good episcope may be used in the teaching of biology, seem seldom to be realized:

(*a*) For preparing enlarged wall diagrams from small originals. To reduce the image size to say about 30 by 20 inches it is necessary to have the paper near the lens. To get the image in sharp focus under these conditions, it is usually necessary to have a longer distance than usual between the object and the lens. This may be achieved by pulling down the picture-carrier away from the body of the machine in a commercial model, or by building a box-like extension frame for a home-made model.

(*b*) For projecting from small solid objects and specimens, such as bones, fossils, flowers, butterflies, etc.

(*c*) For dealing with simple movements and processes.

A model to show how a muscle operates with a limb as a lever system; or a working model, in plywood, of jaw articulation, can be made so that it will fit under the episcope. Its working can then be seen on the screen, just as a small scale dissection (e.g. the cranial nerves of the frog) can be shown, as it is carried out, on the screen.

(4) *The epidiascope.* As its name suggests this is a combination of diascopic lantern and episcope. There is one source of illumination and provision for using either opaque pictures or transparent slides. By the aid of a movable mirror either the picture or the slide is illuminated and the rays of light are passed through one of two lenses. Despite its apparent convenience the epidiascope is usually a bulky and heavy machine and often more costly than the combined price of the two it is supposed to replace.

(5) *The micro-projector* is made specially for projection from microscopic slides. In principle it is a diascopic lantern on a small scale, but, owing to the very short focal length of the lenses involved, it results in a very high degree of magnification. This is a particularly useful apparatus for the teacher of biology, of which the advantages are:

(*a*) It permits considerable magnification, and allows demonstration to pupils not yet skilled in microscopic observation, or when there are not enough microscopes available.

(*b*) It may be used when the preparation of very accurate drawings, from microscopic sections and objects, is required.

(*c*) It may be used to project the images of living organisms.

The important points to note in buying a micro-projector are few and simple:

(*i*) Rigidity and simplicity of structure.

(*ii*) Employment of standard screw-threads, to allow any standard microscope objective lens to be used.

(*iii*) Provision of a cooling trough of water to prevent the death of living organisms from over-heating.

(*iv*) Provision for either horizontal or vertical projection.

(6) '*Over-the-shoulder*' *projector.* This is a diascope with a vertical axis and a reflecting mirror attached to the lens, which turns the image rays through 90°. The lantern slide lies flat on

a glass plate. If this projector is on the teacher's bench, and he has a screen behind him, he can point out the features of the image and operate the machine without having to walk up and down the room. Also, by putting a piece of ground glass over the slide space, or by using clear glass instead, he may draw a diagram with pencil or wax-pencil and the class can watch the process on the screen.

So far we have been concerned with projection apparatus in which an image is formed on a screen from a still object, or from a mechanical structure (in the episcope) or from fine movement of an organism (in the micro-projector). In the study of biology, however, it is also necessary to use simple and compound microscopes and, though these are usually well known to the biology teacher, a few comments may be useful.

(7) *The simple dissecting microscope.* There are many occasions in a school laboratory when a hand-lens falls short of what is needed. It may not lack the necessary optical power, but it requires one hand to hold it. For fine dissection it is sometimes not merely convenient, but even essential, to have both hands free. This freedom may be obtained in three ways:

(*a*) By using a watch-maker's eye-glass, consisting of a lens mounted in an open-ended cone which is held in the eye like an ordinary eye-glass.

(*b*) By having a simple lens mounted in a clip which can be attached to the handle of a dissecting needle or scalpel. Such instruments may be bought from commercial sources or made up with the aid of wire and wood. If spring-clip clothes-pegs are obtainable, they can be adapted.

(*c*) By making a simple dissecting microscope. This consists of a block of wood cut to give sloping supports for the wrist on each side, with a reflecting mirror, and a pillar on which the lens slides for focussing.

(8) *The compound microscope.* For advanced work in school biology, at university-entrance level, a compound microscope is essential. The problem of costs arises. Few schools have enough microscopes, and most schools have not laid out their

expenditure to the best advantage. A little thought makes it clear that even the advanced school pupil does not need so elaborate an instrument as the undergraduate, and that the call for very high magnification is infrequent. Despite this it is common, though mistaken, practice to buy 'the best instrument possible'. This usually means having too few microscopes of a type more elaborate than is needed for general class work, yet not efficient enough to give the very high magnification needed on rare occasions.

A good policy for the equipment of a school biological laboratory may be suggested:

(*a*) The purchase of one good standard microscope, with coarse and fine adjustment, sub-stage condenser and triple nose-piece. As optical equipment:

(*i*) $\frac{1}{10}$-inch dry, or $\frac{1}{12}$-inch oil immersion, objective; preferably the latter.

(*ii*) $\frac{1}{6}$-inch and $\frac{2}{3}$-inch objectives for normal work.

(*iii*) A dividing objective to give 1- and 2-inch focal lengths for low-power work.

(*iv*) A demonstration eye-piece allowing both teacher and pupil to observe together. If this has a field pointer, so much the better.

(*v*) Oculars of ×2, ×5, and ×10 power.

This instrument may be used for general demonstrations by the teacher, and for the setting out of special demonstrations, such as nuclear phenomena.

(*b*) The purchase, for each student (or for as many as possible), of a simple, sturdy microscope with sliding coarse adjustment, threaded revolving fine adjustment, a dividing objective and a ×4 eye-piece. This instrument costs about half as much as the 'students' microscopes' usually bought for school use. It is just as efficient for nearly all routine work. With the saving effected, one good microscope may be purchased to do everything that is necessary. Because they are smaller and cheaper, such instruments can also function as portable models for use on field expeditions, in biological camps, etc.

The microscope, it should be noted, with a suitable condenser lens and a highly intense point light (e.g. the 'Pointolite' lamp), may be used for micro-projection as well as for individual ocular observation.

(9) *Some comments on photo-micrography.* Some of the phenomena observed with the microscope are fleeting or rare and, while a good drawing provides some record, a photo-micrograph is even more valuable. Unfortunately teachers often fail to use it because it is considered impossible, except at considerable expense and with very special apparatus. Records sufficiently good for much school work may be made, however, in one of the following ways:

(*a*) A microscope is set up in the usual manner, with the object evenly and well illuminated. A folding camera (plate or roll film) is loaded with panchromatic film and focussed at 'infinity' on the scale. The camera lens is put close to, and axially above (as near as possible by inspection), the microscope eye-piece. The shutter is arranged to give an exposure (guessed at first, e.g. $\frac{1}{2}$ second), but soon found by experiment. A positive print from the negative is made by contact printing or enlargement.

(*b*) The micro-projector, or the microscope acting as a micro-projector, is set up and an image of suitable size, such as 4 by 3 inches, is projected on to a screen. Cardboard and black cloth are used to ensure that no light, other than that from the lens, falls on the screen. The light is turned out and a piece of bromide paper or a glass negative is put on the screen. The photo-micrograph is made by switching the light on and off. Here again the duration is a matter of experiment.

(*c*) The miniature projector, or a photographic enlarger, is used, in a similar manner, to obtain low-power magnifications from objects mounted on microscope slides.

(10) *Moving picture projection.* 'Moving pictures' are projected by a cinematograph machine. The term 'moving' is, in fact, a misnomer, because what we see on the screen when we watch a film is a rapid succession of still pictures, in which a single action is represented by a sequence of static sections of the complete whole. Thus the lifting of an arm, occupying, say, half a second of time, is shown by perhaps 8, 12, or even more, still photo-

graphs shown to us one after the other. We see each of these for a small fraction of a second; between their appearances the screen is blank (and dark) and from the slight alteration in position of the arm we build up an illusion of movement.

Moving pictures are printed on long lengths of perforated cinema film. The perforations are used by various spur wheels (toothed wheels) to drive the film through the machine, and a special intermittent action holds each frame stationary for a fraction of a second while its image is on the screen. To ensure that we in fact do *not* see the images move there is a shutter of Maltese cross pattern which cuts the light off from the screen while frame movement takes place.

The film used in the professional entertainment theatre is 35 mm. wide with frames 18 by 24 mm. for silent films. In educational films the width is usually 16 mm. In both kinds of film a sound track (for reproducing the sound in 'talkies') reduces the width of film available to provide the long axis of each frame. To compensate for this, 16-mm. sound films have perforations along one edge only, and therefore they cannot be projected with a silent machine. For amateur film production, other film widths are used, and 8-mm. film is now widely used in educational work especially for the new loop films.

Sound was originally recorded mechanically on discs like gramophone records. Later it was recorded mechanically, but printed on the film as a strip of which the varying width and opacity affected an apparatus which reconstructed the original sound through a microphone. In modern films, recording of sound is done by electronic means. The subject of sound recording, though interesting, is complex. Fortunately we can project a sound film while knowing little more than how to put the film in position, control the volume of sound by turning a knob, and setting the machine to run at 24 frames a second, instead of 18 frames, as is the case for silent films.

The cine-projector, whether sound or silent, is basically no more than a special apparatus to give sequential change of picture. However elaborate the machine may appear, and it does seem very complex to anyone unfamiliar with machinery in general, it is quite easy to learn how to operate it. No special knowledge or skill is needed, beyond ordinary common sense, ordinary manual dexterity, and the ability to read the instruction book. Even after half an hour's tuition, teachers who have previously never seen a 'movie' projector have learned to lace (thread, or put in the film) and to control it. After a few hours they have become confident and able to deal with the few faults likely to arise, such as splicing a broken film, replacing a fuse or lamp, etc. The new continuous-run loop film projectors for use in daylight (e.g. Technicolor 800E) are loaded by merely pushing the film cartridge into a slot so there are no lacing difficulties. Silent films only are available in this case.

(11) *Sound or silent films?* Teachers frequently ask which is better, the sound or the silent film? There can be no single definite and correct answer because the question means either too much or too little. When deciding which kind of machine to buy the answer is, if funds allow, to buy a sound projector because it may be used for silent films, while the reverse is not true. The value of sound film lies in the recording of natural sound, associated with the event being shown, and in the use of a spoken commentary to explain the film while it is being seen. Natural sound plays only a small part in school biology: plants make no noise, animals are not articulate and we are seldom concerned with bird song or animal voices. A commentary, however, is useful because it may be given by an expert and accurately synchronized with the film sequence. But a sound projector is not essential. The teacher should know the biological processes shown by the film and be able to speak his own commentary. As in the case of film-strips, a printed descriptive booklet is usually available with silent films.

(12) *Colour or black-and-white films?* The early films were not only silent, they were also black and white. The colour film, invented later, may be projected by sound or silent machines, and is of value to the biologist because colour is an important characteristic in biological structures. Colour films, however, are costly to make, and therefore more costly to buy or hire than black-and-white films. However, just as we have accepted

the conventions of monochromatic illustration in textbooks, and the black-and-white films on the cinema screen, so we can use the black-and-white film in teaching, if we cannot afford colour.

(13) *Buying or hiring films?* The answer here is simple. Films, even in black-and-white, are so expensive that few schools can afford to purchase them. Instead they are hired from commercially sponsored film libraries, or borrowed, or hired at lower rates from a Central Film Library, sponsored by the Department of Public Instruction of the State, Province or country.

(14) *Some special points.* One or two points are worthy of special notice, especially by those who have little experience of using films in teaching.

(*a*) *Maintenance of projectors.* A complex mechanism needs to be regularly cleaned and serviced. While the operator, usually a member of the science staff, can and should undertake simple routine jobs, such as cleaning the 'gate', etc., the machine should be handed over to the agents for annual overhaul. The small cost is amply repaid in trouble-free performance and a longer life.

(*b*) *Film storage.* Whether films are owned by the school, or merely held for a day or two while on loan or rental, they must be stored on proper spools in their special cans. They should be kept in a place which is as dust-free and as cool as possible.

(*c*) *Film handling.* Films are delicate and must be handled with care. They should never be allowed to rub on the floor, not even the blank end or header strip, because in this way dust particles are collected which stick on the gate and cause scratching. Film should be handled by the edges only because fingerprints on the surface look unsightly and collect dust which causes damage. If a film breaks, the machine should at once be stopped. (On some machines there is a tripping device for automatic stopping.) The machine should be inspected to ensure that the breakage is not due to faulty lacing or other mechanical fault. Having re-laced the machine, the broken end should be wound on the pick-up spool to be dealt with later. School films can be spliced after the show when there is time to do the job properly. Other people's films must be dealt with according to instruction and agreement, and these are usually to the effect that the broken film should be returned to the owner for repair.

(*d*) *Film return.* In using hired or borrowed films we have to make sure that the instructions about re-spooling are observed. Some owners like to rewind their own films as part of film-cleaning and check-up. Films must *always* be returned immediately after use on the agreed date, packed according to instructions, and legibly addressed to the owner, whose address should be both inside the film can and on the outer wrapping. Failure to return a film promptly is likely to mean that some other school will fail to receive it at the time it is needed.

(*e*) *Fixed or mobile projector?* Most of the schools where films are used in teaching can afford only one projector. If space allows it is preferably fitted up for permanent use in a special room, or in the school hall. This avoids the risk of damage in moving the machine, and reduces the costs involved in multiplying wiring, plug sockets and black-out. Yet this has the disadvantage that the film cannot be used in the middle of a period to illustrate a special point, and that the class may have to move to another room and it may be impossible to show films at the moment of real need.

(*f*) *Film operator.* The projector and the film are preferably placed in the charge of a single individual. Unless a competent laboratory steward is available, this puts a heavy load on one member of the staff of a school where films are used frequently. The only way to overcome this is to have several members of the staff, and even senior pupils, trained to operate the machine, all working under one staff member, who is looked upon as the real expert.

(*g*) *Projecting conditions.* (*i*) Some machines operate only on alternating current, others on direct current and others on both. To use the wrong type of current results in blown fuses or burnt-out wirings. Therefore the type of current available should be checked before a suitable machine is bought.

(*ii*) Effective viewing requires appropriate seating, good 'black-out', or provisions for 'daylight projection'. Seating must be such that no viewer is either too near or too far from the screen

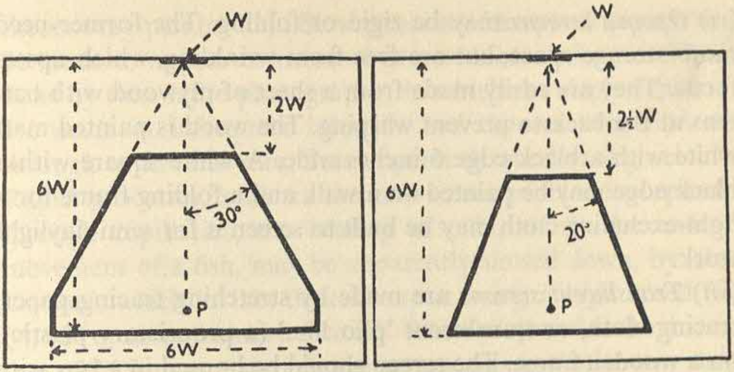

FIGURE 20.—Viewing conditions with different types of screen surface. On left: matt surface; on right: beaded surface. The area of effective viewing is bounded by a heavy black line
W = width of screen. P = position of projector

and no viewer is outside a certain angle beyond which luminosity rapidly falls. (See Fig. 20.)

(*iii*) '*Black-out*' is expensive to achieve and must be accompanied by adequate ventilation, especially under tropical conditions, or even in a hot summer in temperate zones. These difficulties may be avoided by semi-daylight and daylight projection.

(*iv*) *For semi-daylight projection* all that is needed is to shield the screen from indirect lighting. This is most easily done by using a class-room cupboard. The top doors are opened and the screen placed between them. A black cloth is draped over the top of the doors and another pinned across the bottom. (See Fig. 21.)

(*v*) *For daylight projection* a translucent screen is used. A silent film may then be projected directly on to this if the film is laterally reversed in the machine. This cannot be done with a sound film, so use is made of 'back projection'. The light beam is reflected from a mirror on to the translucent screen.

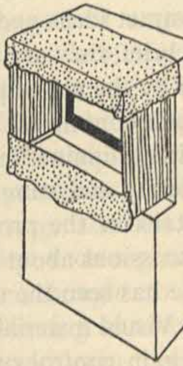

FIGURE 21. — A screen in a class-room cupboard, for semi-daylight projection

(*vi*) *Opaque screens* may be rigid or folding. The former need more storage space, but are free from wrinkling, which upsets focus. They are easily made from a sheet of plywood with battens at the back to prevent warping. The wood is painted matt white with a black edge 6 inches wide. A white square with a black edge may be painted on a wall, and a folding frame for a light-excluding cloth may be built to screen it for semi-daylight work.

(*vii*) *Translucent screens* are made by stretching tracing paper, tracing cloth, or translucent 'plio film' (a proprietary plastic), on a wooden frame. The screen should be housed in a box with folding flaps, which provide protection and act as light traps.

(*viii*) When using a projector all fittings, cables, plugs and transformers, etc., must be arranged so that no pupil can touch or fall over them.

The general values of visual presentation

Having surveyed the materials and machines available and indicated some of the practical problems involved, it is well to inquire what values may be derived from using these visual aids. They may be summed up in a series of brief statements:

(*a*) Visual materials provide non-verbal evidence, allowing the individual to see, and thus to be provided with data to give abstract ideas and unfamiliar concepts more definite meaning. In brief, they are an aid to understanding.

(*b*) By the use of projected materials, either still or moving, we make communal viewing possible. The large image, with its bright illumination and its novelty, commands attention, fosters interest and stimulates effort. The teacher may point out the details of the projected image, ask questions, and hold class discussions about it, thus saving time and ensuring that everyone has seen the things in question.

(*c*) Visual materials, by using enlargement or reduction, help us to gain control over problems of size. We may deal with the very small or the very large because of the scalar control offered by microscope, telescope and camera.

(*d*) Temporal control is offered to us, especially in the case of the moving picture film. Slow processes like plant growth may be made to appear to occur at greater increased rates. This is done by time-lapse photography, in which the single exposures are made at infrequent intervals and the resulting film run through at normal rate, thus apparently accelerating velocity. Rapid processes, such as the movement of blood corpuscles through capillaries, the beating of cilia, or the locomotory movement of a fish, may be apparently slowed down, by 'slow motion', which in fact depends upon using a high speed (i.e. 64, 128 or more frames a second). When projected at the normal rate of 24 frames a second, the action appears to be very slow.

(*e*) Visual aids give us some kind of control over season and location. We may examine records of plant life in the dry season or wet season at any time of the year and, sitting in a tropical class-room, we may see what the Arctic looks like.

(*f*) Visual aids in fact allow us to break down barriers of space and time, and to bring the world into the class-room. We may use the illusion of reality, so well created by the moving picture film, to widen the experiences of our pupils by purely vicarious means.

The characteristics of biology which make it specially suited to visual methods of teaching and learning

Although visual aids are of value in many general ways in education, their use in the teaching of biology must be supported by evidence that the subject needs them. The very fact that many of the earliest uses of photography and cine-photography and many of the early educational films and film-strips were on biological topics is evidence that biology is particularly suited to visual treatment. The teacher who hopes to get the best out of the visual approach does not merely accept such a general approach, however, but should give further thought to the matter. Attention may be drawn to the following characteristics and difficulties facing those who teach and learn biology in schools.

(*a*) Biological materials range from the microscopic to such vast organisms as the extinct giant reptiles or the existing whales.

Visual presentation, by photography, modelling and microscopy, allows us to deal with all these. With the modern electron microscope, photographic records are made of even ultramicroscopic organisms and, though no school can own such a machine, the photographs may be obtained from the popular scientific press.

(*b*) Biological materials range in space and time. Some exist on the other side of the world, others existed in a remote past and some are subject to periodicity. The temporal and spatial control, which we have already noted to be possible through visual methods, helps the biologist to overcome these problems.

(*c*) Events in sequences are often widely spaced: for example, in a complicated and lengthy life history. By visual means we may present and examine the whole series at one time.

(*d*) Some biological processes are complex; e.g. the nuclear phenomena relating to mitosis and meiosis, the phenomena of genetic inheritance, and the relations involved in the nitrogen cycle. With visual aids we can simplify, analyse and demonstrate in various ways to make understanding easier for the pupil.

(*e*) Many biological structures such as the *truncus arteriosus* of the frog's heart are complex and not easily understood by the beginner. With an enlarged model we may demonstrate such structures, so that understanding becomes more possible.

(*f*) Morphological relationships demand a considerable degree of ability for three-dimensional perception, as in understanding the transition zone between root and shoot, the structure of a growing tip, or the carrying out of a dissection. With three-dimensional models and stereograms we help pupils to achieve this special kind of perception.

(*g*) Some of the technical processes of practical biological work, such as cutting or mounting a section, or dissecting the cranial nerves of a dogfish, involve many stages. After a single demonstration the pupil finds that he cannot remember exactly the sequence and procedures. To repeat them continuously is impossible, but a set of stage-by-stage photographs, available for frequent reference, helps to overcome such difficulties.

(*h*) Biological phenomena may be characterized by very slow or very fast velocities. The devices of time-lapse photography and high-speed cine-photography help us to see and understand processes like the growth of a root hair or the action of the chameleon's tongue.

(*i*) Biology is the study of life, but too often we spend far more of our time in dealing with dead plants and animals than in studying living ones. While the school garden, the vivarium and the aquarium help us, there is also a place for visual methods, especially for the moving picture film, with which we may see, perhaps in natural colour, the movement and behaviour of organisms of all kinds.

(*j*) In school biology we are often concerned with the study of organisms removed from their natural environment. Through the use of visual aids the boy a thousand miles from the sea may gain some understanding of the problems which beset the hermit crab.

(*k*) The study of biology should lead to a greater understanding of the biological aspects of social phenomena, the dependence of Man on nature, the relations between biogenesis and public health, and the effect of birth- and death-rates on population. Here is a rich field for the application of the visual approach, one so far little explored and yet of tremendous significance.

The supply of visual aids for school use

The earlier pages of this chapter have referred to many practical points, but have been mainly concerned with the arguments in favour of using visual aids. When a teacher decides to make use of visual methods and materials, however, he has to find out how they may be obtained.

Visual materials suitable for use in the teaching of biology are available from many sources which are not always known to teachers. It may therefore be of help, especially to the less experienced, or to those in more remote places, to offer some suggestions on the location of teaching materials in general.

Commercially produced materials vary in cost and sources of supply and teachers who wish to know what materials are available could well explore the following:

(*a*) the brief list of names and addresses given in Appendix J
(*b*) advertisement pages in educational and related magazines which are usually available in public libraries or in such cultural organizations as the British Council, Alliance Française, U.S.I.S. and the like
(*c*) catalogues prepared by local producers and local agents
(*d*) information sheets from the local education office.

Commercial materials are usually available for purchase, on hire and as free gifts made in the interests of prestige advertising. Purchase obviously depends upon the availability of funds and may be subject to special forms of central control—one advantage of which could and should be a maintenance and spares service. Hiring of visual and other materials can make available a greater variety of material than purchase for any given sum.

Free gift material can be very valuable to the biology teacher. Potential sources can be identified from advertisements. An official letter addressed to the local agent of a likely firm will usually result in a supply of materials which, though centred around a particular product, are useful for general teaching. Many firms produce brochures, posters, maps, diagrams and even small constructional kits. Such gifts should be acknowledged at once and integrated into the background of teaching.

Making visual aids. There are two good reasons for considering self-help in visual education.

Firstly, it reduces cost and may thus make it possible to have materials we cannot afford to buy from commercial sources.

Secondly, it is often more effective. A diagram, model, photograph or even a film may be made in *local* terms.

One of the great dangers of the visual medium is that we may be forced to use a film made for European conditions in the teaching of children in Africa or India.

The resources of available materials, skill and money often make it possible for the biology teacher, aided by his pupils, to make a considerable number of visual teaching aids. As far as materials are concerned, a small store of plywood, sheet tin, cardboard, paper sheets, paint, brushes, etc., is needed. Much of this may come from 'junk'. The skills needed are simply those of using brush, pencil and simple hand tools. The last are usually available in any school where there is metal-work or wood-work. The costs are reduced when scrap material is used and by suitable purchases of what cannot be made, e.g. a lens for a film-strip projector, which can consist of a simple bi-convex eye-glass lens bought from an optician.

Apparatus. The following should be within the means of most teachers:

1. Screen for projection, made from plywood.
2. Daylight projection screen and mirror for back projection.
3. Simple episcope for use with translucent screen.
4. Simple film-strip projector.

Materials. (1) *Models*. The materials to be used depend upon the kind of model, as will be seen from the following brief descriptions.

(*a*) A mechanical model to demonstrate the action of the jaws of a snake, or the sequence of action in the pollination of a flower, requires plywood, metal, wire, string and a clockwork motor.

(*b*) Making models which are representational but not to a strict scale is comparatively simple, though of course the general proportions should be preserved. While proprietary materials or artist's modelling clay, are excellent for the purpose it is convenient (and much cheaper) to use potter's clay, or even to collect clay from the river bank. Large models will need a supporting framework of wood or wire.

(*c*) The making of a scale model is a more exacting task, but provided the teacher is prepared to use effort and ingenuity it is within the limits imposed by a school laboratory. As an example of procedure the preparation of a scale model to show the external form of a simple brain, e.g. a fish, may be considered. (This may well be one of a series to show the evolutionary development of the brain.) The procedure, in brief outline, is as follows:

(*i*) A series of transverse sections is cut through a complete brain. If a rocking microtome is not available, a freezing microtome or a hand section cutter may be used. These sections may be quite thick, say 100 μ. Thin sections are better, but make a larger task.

(*ii*) All the sections are mounted in order, as many as possible on a slide. They are stained in a suitable gross stain, such as Delafield's haematoxylin and eosin.

(*iii*) The scale of the model is decided upon. Suppose it to be a magnification of 100. Then the thickness of the model of each section is 100 times the thickness of the section. In order to illustrate the method suppose this to be 0·01 mm.

(*iv*) Each section in turn is projected at 100 × magnification on to a sheet of suitable material, which must be 1 mm. thick in this case. Suitable materials are:

Blotting-paper or newspaper soaked in melted paraffin wax laid one on another to achieve the required thickness.

Paper on which melted beeswax has been poured, and a cover sheet added, and the 'sandwich' rolled out to required thickness with the aid of a warm metal roller running over two metal strips of the required thickness.

Very fine clay rolled out on paper to make a thin layer of 1 mm. (or other) thickness.

(*v*) The outer edge of each section is cut out by means of a sharp-pointed scalpel.

(*vi*) The sections are assembled one above the other in correct sequence so that the solid model is built up. To give strength it is usual to drive pins down through the sheets at intervals. A stout wire may be pushed through the whole model.

(*vii*) The edges are then smoothed off. Where wax is used this is done with a warm modelling tool or the handle of a warm spoon. In a clay-based model the surface is damped and worked smooth by gentle rubbing or pressing.

(*viii*) After drying, the model may be painted. Oil-paint may be used on a wax model. In clay models a coat of glue-size, or dilute glue, is given. When this is dry, the model may be painted with water-colour paint. In both cases varnishing gives a permanent finish.

(*d*) When several copies of a simple model, e.g. a transverse section of an earthworm, are needed, plaster of Paris may be used to cast copies of the original model, as follows:

(*i*) The original model is made in Plasticine, clay, etc. It must have no undercut surfaces.

(*ii*) A moulding-box, either of wood or cardboard, is made. (The simple process of running a flat strip of Plasticine around the edge of the model may be used.)

(*iii*) A mixture of plaster of Paris in water is made. The consistency is very thick, but just allows pouring.

(*iv*) The surface of the model and moulding-box (inside) are given a very thin smear of thin oil or soft soap.

(*v*) The plaster is poured into the moulding-box to cover the model completely, and allowed to set.

(*vi*) When dry and hard, the mould is removed from the box, and the model extracted.

(*vii*) The mould is put back in the moulding-box, the other way up.

(*viii*) New plaster is made up and poured into the moulding-box and into the mould. It is allowed to dry.

(*ix*) The copy is removed and the mould is used in the same way to make as many copies as are needed. (See Fig. 22.)

(*x*) The copies are treated with glue-size, paint and varnish.

However difficult this procedure appears when described here, it is quite easy to perform. Models made by such a process may be of great help in teaching. The only other precaution to note, beyond the avoidance of undercutting and the use of oil or soap to prevent sticking, is that the setting of plaster of Paris is an irreversible reaction. Waste or excess plaster must *not* be poured into sinks or drains. It should be poured, while still liquid, into a bucket of water and emptied into an open drain. Ordinary plaster of Paris is bought from shops dealing in paint and plasterers' materials. Quick-setting plaster of fine texture, giving a very hard product, is obtainable from biological supply dealers, or a dentists' supply agency.

(*e*) *Pupils' models.* To make a solid model is an effective way of learning. While it may be unwise for pupils to spend too much time on the more elaborate procedures, they should be encouraged to overcome difficulties by using quickly made models. For this reason supplies of Plasticine and clay should always be readily available.

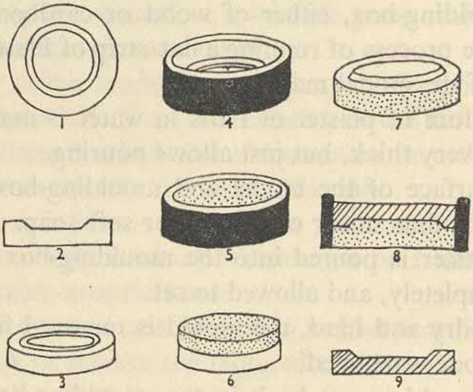

FIGURE 22.—Making a plaster cast. 1, 2, 3 show the original to be copied. 4, 5, 6 show the making of the mould. 7, 8, 9 show the making of the cast. The casting box is made by placing a plastic wall round the original

(*f*) *Storing modelling materials.* Clay should be wrapped in several layers of damp cloth, or be rolled into balls, covered with a damp cloth and put into a box. Plasticine should be kept in a box. Plaster of Paris must be kept absolutely dry in an air-tight box.

(2) *Pictures.* Postcards, pictures cut from magazines, etc., should be collected and properly stored. Postcards may be kept in envelopes arranged in suitable sets. Each card should carry a number to indicate its set. The title and set-number should be on the outside of the envelope.

Pictures cut from magazines may be suitably arranged and pasted on to very stout paper or cardboard. If this is then covered by a layer of cellophane, damage or wear and dirt are greatly reduced.

(3) *Large diagrams.* It is often desirable to have certain features drawn on a very large scale. This may be done on cloth, paper or cardboard. When a flexible base is used, one edge may be fixed to a wooden strip or rod, so that it may be rolled up. In drawing such a diagram, how is the enlargement made? Many teachers can copy a small diagram on an enlarged scale by free hand methods. For those who cannot, there are three 'mechanical' methods:

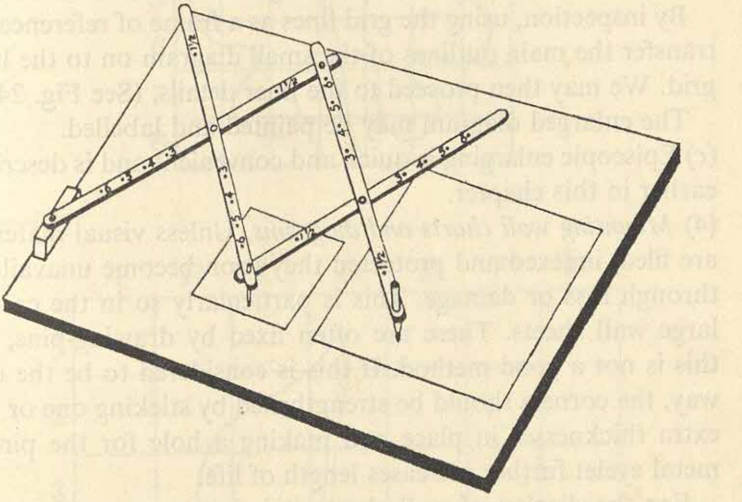

FIGURE 23.—A pantograph. The pantograph in use at a scale of two linear magnifications

(*a*) The pantograph is a device for enlarging by simple tracing. The apparatus (approximately 1 U.S. dollar, 4 shillings sterling, 3 rupees Indian) is placed on a drawing-board. It is set to the desired scale of magnification. The pointer is traced over the small diagram it is desired to enlarge. A tracing of this, at enlarged scale, is made by the pantograph pencil on a sheet of paper pinned on the drawing-board. (See Fig. 23.)

(*b*) 'Gridding'. Suppose we desire to enlarge a diagram twenty times. We draw a suitable square (or rectangle) round the original figure, using a medium-soft pencil and light strokes if it is in a textbook. This is divided into a series of small squares with sides $\frac{1}{10}$ inch, 5 mm., or whatever appears suitable. On a large sheet of paper we then draw a square (or rectangle) twenty times the size of the first. We divide this into squares with sides twenty times as long as those of the first. For reference purposes we label the squares A, B, C, D, etc., along one edge, and 1, 2, 3, 4, etc., along the other. Any square in either grid may now be identified and corresponding ones found at once.

By inspection, using the grid lines as a frame of reference, we transfer the main outlines of the small diagram on to the large grid. We may then proceed to the finer details. (See Fig. 24.)

The enlarged diagram may be painted and labelled.

(*c*) Episcopic enlarging is quick and convenient and is described earlier in this chapter.

(4) *Mounting wall charts and diagrams.* Unless visual materials are filed, indexed and protected they soon become unavailable through loss or damage. This is particularly so in the case of large wall sheets. These are often fixed by drawing-pins, but this is not a good method. If this is considered to be the easy way, the corners should be strengthened by sticking one or two extra thicknesses in place and making a hole for the pin. A metal eyelet further increases length of life.

For the display of wall sheets it is better to make special frames to take the sheets either horizontally or vertically. Vertical sheets are placed between the top and bottom battens, while the middle and bottom are used for horizontal sheets. The dimensions should be chosen to suit a standard size of paper, such as the imperial drawing sheet.

A still better method is to provide each sheet with a wooden batten, 1 inch wide and a $\frac{1}{4}$ inch thick, along top and bottom. The sheets are then hung by a string through two holes in the top strip.

An alternative, if several sheets refer to one topic, is to put them into a large 'pad' by having two wooden battens along the top edge, one each side of the set of papers.

(5) *Labelling and colouring*. Descriptive lettering, guide-lines and

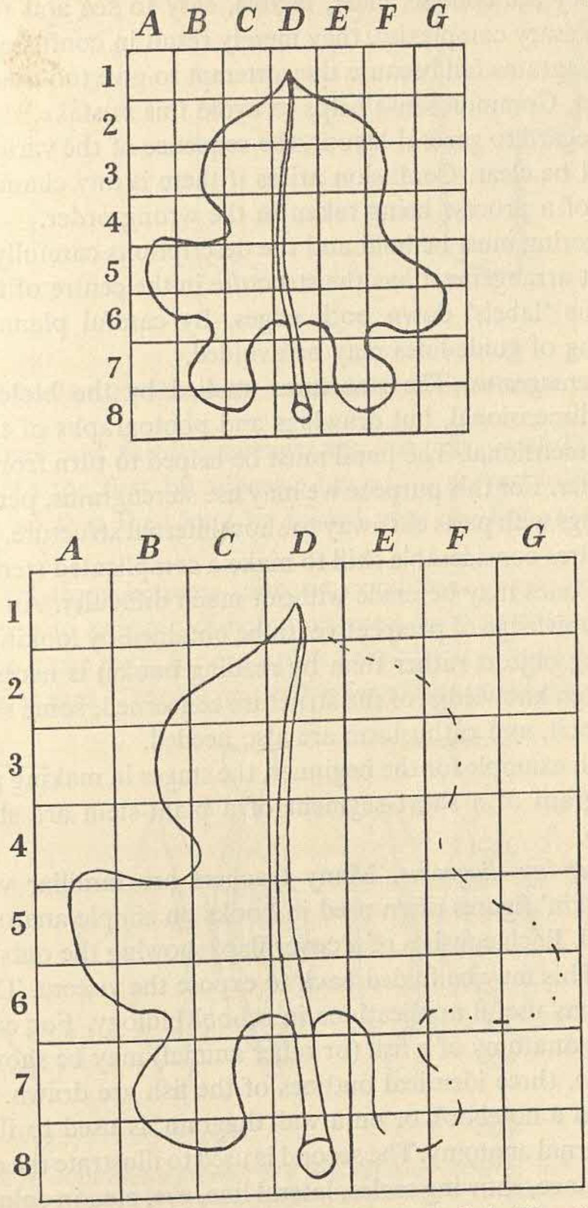

FIGURE 24.—The enlargement of diagrams by the 'grid' method

colours are used to add meaning to pictures and diagrams. Unless they are concise, clear, legible, easy to see and free from unnecessary complexity, they merely result in confusion. Many wall diagrams fail because they attempt to give too much information. Common sense helps to avoid this mistake.

In regard to general layout, the sequence of the various parts should be clear. Confusion arises if there is any chance of the parts of a process being taken in the wrong order.

Lettering must be bold and the descriptions carefully placed. A neat arrangement has the structure in the centre of the sheet and the 'labels' down both edges. By careful planning, the crossing of guide-lines may be avoided.

(6) *Stereograms.* The structures studied by the biologist are three-dimensional, but drawings and photographs of them are two-dimensional. The pupil must be helped to turn from one to the other. For this purpose we may use stereograms, perspective drawings with parts cut away to show internal structure. Though it requires considerable skill to make a complicated stereogram, simple ones may be made without much difficulty. An elementary knowledge of perspective (to be obtained by looking at and drawing objects rather than by reading books) is necessary. A thorough knowledge of the structure concerned, some skill with the pencil, and enthusiasm are also needed.

As an example for the beginner, the stages in making a simple stereogram of a short segment of a plant-stem are shown in Fig. 25.

(7) *Over-lay diagrams.* Many teachers are familiar with the 'mannikin' figures often used in books on simple anatomy and first aid. Each consists of a cover flap, showing the outside skin layer. This may be folded back to expose the viscera. The technique has useful applications in school biology. For example: (*a*) The anatomy of a fish (or other animal) may be shown. For instance, three identical outlines of the fish are drawn. One of these, in a notebook or on a wall diagram, is used to illustrate the internal anatomy. The second is used to illustrate the external appearance, showing scales, lateral line, eye, etc., in colour. The third may show the arrangement of the myotomes and muscles.

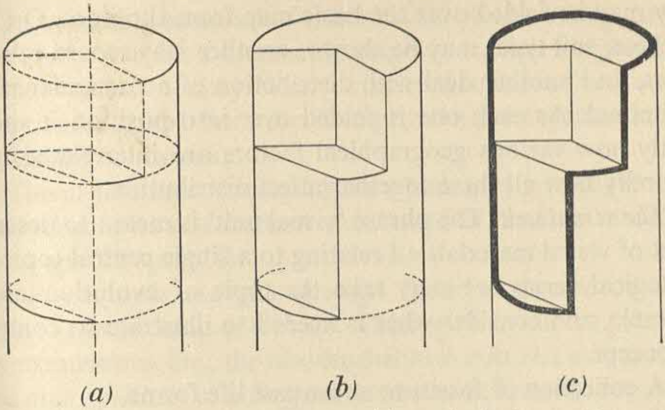

FIGURE 25.—The stages in making a simple stereogram

The second and third drawings are cut out carefully, and attached to the first by adhesive hinges, in correct order and position, so that they may be folded over the first one. (See Fig. 26.)

(*b*) The relations between climatic conditions, physiography, soil types and organic distribution may be demonstrated by drawing a basic map, for example of the physical geography of a particular area. Transparent cellophane flaps are made so that

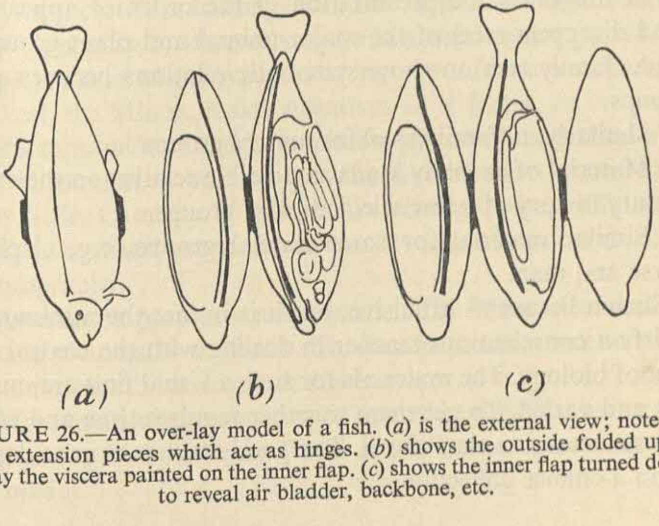

FIGURE 26.—An over-lay model of a fish. (*a*) is the external view; note the black extension pieces which act as hinges. (*b*) shows the outside folded up to display the viscera painted on the inner flap. (*c*) shows the inner flap turned down to reveal air bladder, backbone, etc.

they may be folded over the basic map from the sides. On one of these, soil types may be shown; another may record rainfall areas, and another deal with distribution of a particular plant or animal. As each one is folded over into position it shows firstly how various geographical factors are interrelated, and secondly how all these together affect distribution.

(8) *The visual unit.* The phrase 'visual unit' is meant to describe a set of visual materials all relating to a single central topic. In biological terms we may take the topic of evolution as an example, and consider what is needed to illustrate so complex a concept.

(*a*) A collection of fossils to show past life forms.
(*b*) A collection of models if fossils are unobtainable.
(*c*) Pictorial reconstructions of life in the successive major geological periods.
(*d*) A time and sequence chart to illustrate the succession of the geological periods.
(*e*) Maps of the world at one or two key points in geological history.
(*f*) Maps of the present geographical distribution of a few selected organisms.
(*g*) Diagrams of embryological development of a few types.
(*h*) A diagrammatic presentation of the order of appearance (and disappearance) of the major animal and plant groups.
(*i*) A 'family tree' to show systematic relations between plant groups.
(*j*) Similarly, a 'family tree' for animal groups.
(*k*) Material of as many kinds as possible relating to the evolutionary history of a few selected plant groups.
(*l*) Similar material for some animal groups, e.g. elephant, horse and man.

Such a list seems extensive, but it is in fact the minimum to satisfy a conscientious teacher in dealing with the central concept of biology. The materials for such a visual unit are numerous and varied. To get them together requires time and effort. It is necessary to plan ahead. The good teacher cannot depend upon a chance collection.

In collecting material of this kind, pupils may help, and the task may well be a large-scale project or a job for the school natural history society. When completed such a collection is not only useful in the laboratory, it may form a permanent exhibition in the school museum.

This is just one of many topics which may be treated in this way. Examples of others are mentioned in connection with the museum (Chapter X).

(9) *Photographs and photography*. Photographs are important aids to the teaching of biology. Although they can be purchased from museums, etc., the wise teacher also cuts out and preserves the many pictures of biological interest to be found in magazines. Moreover many teachers are interested in laboratory photography and some comments on apparatus suitable for this have already been made (p. 182). A few other points may also be noted:

(*a*) The modern move in the field of visual education is towards a smaller format and other kinds of simplification. From the costly complications of 16-mm. cine films in colour and with sound there is now a move towards the use of 8-mm. stock to make a single-concept loop film which can be shown in daylight, and which will run continuously in a simple projector with very easy cartridge loading, as in the Technicolor 800E machine (see Appendix J). Recently there has been a great growth of small cameras of the type known as 'sub-miniature'. One of the earliest, the Minox, makes negatives 11 × 8 mm. on film which is 9·5 mm. wide. Other sub-miniatures use 16-mm. film which can be bought in bulk so that the cost of each photograph is very little. Cameras of this small size may prove useful to the biology teacher, especially as they reduce the costs of colour photography.

Another important development is the 35-mm. camera producing pictures 24 × 18 mm. This makes them an excellent basis for amateur film strip production.

Most roll film cameras can be adapted to use 35-mm. cinema film giving 36 by 24 mm. frame sizes. Three adjustments must be made:

(*i*) The spool ends are built up with coils of paper strip, so that the spool takes 35-mm. film, centrally placed, instead of the original film (2¼ inches wide). (See Fig. 27.)

(*ii*) A scale of revolutions for the winder key is worked out, so that when it is turned to each successive calibration the film is advanced 40 mm. This is necessary because 35-mm. film has no numbered backing paper and the usual red inspection window must be covered up.

(*iii*) The viewing screen, 3½ by 2½ inches, has to be marked out to show the position corresponding to the new frame size of 34 by 24 mm. This may be done by a thin Indian ink line on the ground-glass surface.

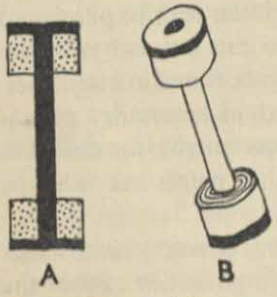

FIGURE 27.—Adapting a film-spool. Adapting a larger spool for 35-mm. film

With this apparatus all the original material may be photographed on plates. These are then arranged in a suitable order and the negatives copied on 35-mm. film, thus producing a positive film-strip.

(*b*) *Dark room.* Many schools cannot spare a separate room for photography. This difficulty is readily overcome by using a portable dark room. This is a light-tight box, with two light-trapped apertures for the hands, and a marked aperture at the top if it is desired to use a safe light in the box. The loading of plates and films into their carriers may, however, be 'done by feel' with a little practice.

(*c*) *Photographic processes.* Lack of space makes it impossible to enter into the developing and printing of films, etc. Suitable books on the subject are given in Appendix F. A few rules should always be observed:

A simple optical exposure meter is needed to determine exposure. The lighting used, exposure given, etc., should always be recorded. The record may provide the basis of experiment. A single well-known brand of materials should always be used. A simple standardized technique is desirable.

Using visual aids in the class-room

The basic problems of visual education lie not in the sphere of apparatus or technical procedure, but in the processes of teaching and learning. Unfortunately we know less of these than of our apparatus and technique. However, some guidance may be offered to those who are turning to the visual approach for the first time.

First of all, visual aids must be used for a particular purpose. To 'have a film-show' is often mere entertainment rather than education. There must be a particular problem or difficulty to be faced. The teacher should have assured himself that a visual approach to its solution is likely to be more effective than an approach, such as reading, discussion or practical work. The teacher must also decide whether he wants the visual material to give new factual information or to provide a background experience to make the acquisition of new knowledge easier at some later stage.

Next, it is necessary to decide what visual aids are to be used, and then how they are to be used.

For a variety of reasons many teachers make the mistake of trying to use the complex things first. They feel they have to start with a moving picture film. This is a mistake, because the handling of the machine requires confidence and skill. Its use often involves changes from normal class-room procedure. Moreover, the teacher has little control over a film, as it may not fit easily into his own lesson plan. He may soon find that the film is dictating what he must do. If there are any golden rules concerning the use of visual aids, one of them is: 'start as simply as possible'. A single picture, a model or a film-strip, specially made for a job, may be of more value than an elaborate film which covers too much and is possibly based on an environment unknown to the pupils.

Let us remember that in visual education the most important item is the class we are teaching. It is the children we are trying to help. The following points are worth thinking about:

(*a*) The material we present to children must be of interest to them, or must stimulate their interest, thus commanding attention and arousing effort, the first steps towards achievement.

(*b*) We should try to achieve a balance between what the child can understand in terms of his own experience and the new problem to be solved before it can be understood. What we offer must neither be so easy as to be boring, nor so difficult as to be discouraging.

(*c*) Our material should call for a response and encourage activity, because learning is an active process and *not* passive absorption.

(*d*) We must prepare the way, by talk, demonstration, discussion, reading and practical work. What we show to our pupils may then help them forward instead of leaving them in a muddle.

(*e*) We cannot expect all pupils, or even any one person, to get everything out of a film, film-strip or a picture, on one single showing. There should be time for a film to be seen more than once, just as there should be time to study models or browse over charts and diagrams.

Thus, when we put our ideas into action, there are four stages to be considered:

(*i*) Orientation. Building up an attitude or 'set of mind'; defining a problem.

(*ii*) Viewing. Seeing the strip or film more than once.

(*iii*) Interpreting. Discussing the contents, the problems solved and those still unsolved.

(*iv*) Response. Activity on the part of the pupil, further reading, an experiment; formulation of a new idea, etc.

Using a film-strip. To illustrate these stages a film-strip on the life history of the frog may be considered.

It is most likely to be used with junior or middle school pupils who may or may not be familiar with the idea of life history, and we must bear this in mind.

(*i*) *Orientation.* We make use of discussion and common experience: What are frogs? Where are they found? What do they eat? Do they live in the same place all the year round? What do we know about how they grow? Who has collected frogs? Who has seen their eggs? Who has seen tadpoles? Such questions bring out some information. This adds to the knowledge of those who have little to start with.

The kind of question to be used depends upon many factors. Not least important is the location of the school. Frogs are absent from some regions, rare in others and of abnormal and specialized types in other places. Thus, the questions asked may be a search for answers based on direct experience. On the other hand they may be derived from teaching and reading. As teachers, therefore, we must plan our questions carefully, according to our own circumstances.

After questions and discussions, including, we hope, descriptions of experience, it is a good plan to try to sum up the extent of our knowledge. It is useful to do this by making two lists, with the help of the class. These lists may be written up on the blackboard like this:

What we know about frogs
They are Amphibia and live on land or in water.
They have lungs and breathe air.
They eat insects caught by the tongue.
Their young are called tadpoles.

What we do not know
Why the tadpoles live in water.
How the tadpoles breathe.
What happens to the tail of the tadpole.
Why the frog has no scales as lizards have.

These are samples of the position we may expect. They are incomplete, show misunderstandings and ignore some important points. But they are due to the work of our pupils. We must follow them up. We must note neglected points and see that they receive attention later on.

(*ii*) *Viewing*. It is assumed that we have the suitable physical conditions for viewing. How, then, should we look at the filmstrip? Should we take it frame by frame, discussing each in detail before going on? A good film-strip has its own unity and, on first showing, this should be preserved. So we had better look right through the film-strip, as a whole, and fairly quickly. In this way we go on building up the general background.

Next we may proceed to deal with the strip frame by frame, giving, say, half a minute to each for question and answer. In doing this it may happen that we find the strip is best divided into groups of frames, each group having a central theme. These themes may be, for instance:

1. Frogs and where they live.
2. Frogs in relation to other animals.
3. Stages in the life history of the frog:
    - *a.* Egg
    - *b.* Tadpole
    - *c.* Adult.
4. Problems frogs and tadpoles have to overcome—feeding, breathing, locomotion, etc.
5. The life history of the frog in relation to evolution.

Our next step is then clear. We go back to the beginning and follow each theme completely and carefully, discussing it in detail before moving on.

Finally we may run through the whole strip again, very quickly, to get back its wholeness and continuity.

By this time many questions may have been suggested in our minds. For example, how much time is needed for all this? The answers depend upon experience and must be related to the capacities and experience of the class. We must remember, too, that many children have to learn how to look, see and understand.

(*iii*) *Interpretation.* Some interpretation has obviously taken place while looking at the strip, but greater opportunities arise afterwards. There are many methods of interpretation, but a convenient starting point is given by the two lists made earlier. How far has the film-strip confirmed the accuracy of our list? What new facts has it brought to light? What problems have been solved? What difficulties still remain unsolved? The teacher has to help the class to find out and decide upon answers to these questions.

(*iv*) *Response*. Every critical thought, suggestion and discussion is an important response. But we should go further. We have problems left unanswered by the film-strip. For instance: 'How is the tail got rid of?' We must ask for suggestions, refer to books on the subject, rear some tadpoles, examine some slides. The responses are likely to be varied and may spread over several days or weeks, but they are the really important part of the whole process.

At the end, the responses should be put into a definite form, such as serial drawings of the life history of the frog, with descriptive notes.

This is not the only way, nor even the best way of using a film-strip in the class-room. It is only a guide. But it has been thought out carefully from practical experience. Hence it is likely to be more effective than the showing of a film-strip without careful preparation. A wise teacher uses a plan of this kind and, from the experience so gained, gradually improves his technique.

Using a motion picture film. Our procedure should be very similar to that for a film-strip. The film, however, is less readily controlled: e.g. we cannot so easily start in the middle, go back a few frames, etc. It is likely to show more material and experiences, so we must make some modifications.

The most important point is that the teacher must have a complete knowledge of the film through the reading of the descriptive notes and by having a thorough preview of the film. We must make a note of all the special difficulties and places where the commentary or caption needs further description or where action in the film needs fuller explanation. The descriptive notes must be examined critically. The general 'story' of the film should be reduced to a short statement, to be used as an introduction. Attention should be paid to the 'sequences' (roughly corresponding to the groups of frames in a film-strip), to the use of animation, natural photography, 'flashbacks' and any other devices used by the maker of the film.

Having had his own first view of the film, a good teacher arranges a second viewing with one or two members of his class. Their attitude gives a guide to the reactions of the rest of the class. He is then able to make better plans for the showing of the film and his method of presentation.

Lastly, the film may be dealt with by working through the four stages suggested for the film-strip.

Comments on evaluation

This chapter suggests and may even show that visual aids offer an effective and essential contribution to the learning and teaching of biology. However, we should remember that all techniques have their limitations. Children are not all the same. They, too, have their limitations. Moreover, visual aids are means and not ends in education. Each of these points is worth a little attention.

Visual aids are only one form of teaching aids. They should be used only when it is probable that they may be more helpful or useful than other means. They should never be used as the *only* approach, and should *never* take the place of direct experiences of real phenomena, if these are available.

It is true that many children depend to a great extent upon visual data in learning. But children differ from each other. All of us have different abilities for visual memory, memory for design, patterns and three-dimensional perceptions. Therefore we must make allowances for the effect of visual aids on different individuals.

We must also remember that, while pictures are 'real' to some extent, diagrams, graphs, etc., are abstractions. Children of all ages, even senior pupils, differ in their capacity to appreciate abstraction. An unsuitable visual aid, even a potentially good one wrongly used, ceases to be an aid and becomes a hindrance.

Lastly, it must be repeated that visual aids are means, not ends in themselves. Our primary concern is with the education of children. We must help them to learn more quickly and more effectively, widening their interests, guiding their activities, influencing their outlook, fostering their social development. In these aims, visual aids may play a useful and effective part. However, if machines and techniques become of more concern to teachers than their educational aims, there is great danger. Our responsibilities to children are far more important than the care and use of apparatus and machines.

CHAPTER X

MUSEUMS AND SCHOOL BIOLOGY

The public museum

The place and importance of the museum in general education have received wide recognition only recently. Museums have a long history in some countries, though not in others. They have reached their greatest development in places where education also has a long history and has become highly organized. Even in such places the museum tended at first to be a collection, often haphazard, satisfying curiosity rather than the desire to know. Even when museums became well organized, covering many branches of knowledge, there was a tendency to think only of collections. Slowly it came to be realized that the collections had some educational value. The museum visitor could be given something of greater significance than curiosity. Only lately has come the realization that those who use museums include not only adults, but children. In this book we have to think about children.

In some countries museums are still uncommon. In others the possibilities of the museum in the education of children have not yet been recognized. A summary of the position in countries where thought has been given to these matters may be of help to teachers everywhere.

Interest in the educational purpose of the museum is no longer the concern of separate countries, but is now considered internationally. Under the sponsorship of Unesco, there is an International Seminar on the 'Role of Museums in Education' and a 'Division of Museums' has been set up in Paris.

An important result of this wider interest in the museum is the realization that its educational possibilities must also be thought of in sociological terms. Education itself is a social force, the most important of all the social services, and the museum should play its proper part. This leads to wide issues, and one of these may be mentioned: the museum can no longer be regarded as merely a place for 'pure' knowledge. It must be concerned with it, but also with the social significance of this knowledge.

The argument behind these new attitudes towards the museum is now widely accepted. In order that the attitudes may gain acceptance in all countries it is necessary that the argument should be known. It is here given briefly.*

Although we live in and are dependent upon a three-dimensional world of objects, education, particularly in the later stages, tends to be divorced from it. We replace the concrete by the abstract, and books, words, pictures and figures come to stand for real things. Pupils often tend to gain knowledge without understanding. It is true that thought must be concerned with ideas, but experience must also be concerned with things. The convenience of handling 'abstract' materials, instead of things, is obvious but dangerous. To avoid this danger education should be concerned with people and things as well as ideas. Opportunities are sometimes limited. They may be greatly extended, however, by developing and using the museum. The museum is a carefully selected sample of reality.

That, then, is the main argument. It is necessary, however, to look at the matter in more detail and to realize that the museum must meet the needs of three distinct groups:

(1) *Beginners*, who need a simple exhibition of material presented in a colourful and interesting manner.

(2) *Students*, who come with some degree of knowledge for the purpose of following up a special study or topic.

(3) *Experts*, who use the museum as a reference collection for their research work.

For teachers the first group is most important, though, at sixth form level, the advanced pupil may be regarded as a student. To meet the needs of the beginner, special children's museums, or children's sections, have been developed in some cities.

Many pupils live at a distance from the museum and may be unable to visit it. This difficulty is overcome by the development of small-scale collections for loan to outlying schools. Each of these collections must be carefully made. Each should deal with a special subject or topic in the school syllabus and curriculum. A collection of this kind is put in a strong box, made so that it may be opened out as a display cabinet. The contents need not be restricted to museum specimens and it is usual to include illustrative material and a descriptive booklet. When a school party is to visit the museum, arrangements should be made in advance so that the best use of the collection may be made. There must be careful planning, so that specific exhibitions may be prepared and the more general collections may be used effectively.

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* This statement is partly based upon the Introduction, by Dr. D. A. Allen, to Unesco's Report, 'Some papers on the role of museums in education'.

It is generally agreed that, if the museum is to make the maximum contribution to education, both museum and educational authorities should plan together.

Museum arrangements are, briefly, as follows:

(*a*) It is essential to provide introductory or 'orientation' materials in the form of 'key' or 'guide' collections. The purpose of these is to provide the beginner—and most pupils (besides many adults) are beginners—with an overall view of the contents of the museum. The visitor should be able to understand them quickly and easily. These materials should show only essential and logical relationships. They should provide a simple guide to the layout of the museum as a whole. This introductory material is usually placed in the entrance hall of the museum.

(*b*) The contents of the museum are divided, of course, into sections according to subject. Each of these occupies a particular place. The visitor enters a section with some understanding because of the 'key' materials. A more detailed survey of each subject division is usually presented in the form of tabulated data or a schematic diagram.

(*c*) In the main collections it is desirable to pick out the essential items for the beginner. Otherwise his attention is likely to wander and then he becomes tired or bored. The essential items, like all others, should carry a label for the informed or specialist visitor. But they should also have a simpler label, with less technical detail and terminology, for the benefit of the beginner. This may be printed on a card of special colour, so that it at once attracts attention.

(*d*) It is desirable to have small special collections that may be handled by pupils. (Learning does not take place only through looking and listening.)

(*e*) If specimens are to be handled, there should be facilities to keep them safe and free from damage. Even the commonest objects represent the expenditure of time and money. Such collections are best kept in a special room, with work benches and good lighting. It is also useful to have available a supply of clay for modelling, though this, together with drawing materials and hand-lenses, may be brought by the pupils.

(*f*) A member of the museum staff should undertake special duty for school visits. The usual 'guide-lecturer' is suited to adult needs, but may be less successful with schoolchildren. Some museums appoint a teacher for this particular purpose. In other places teachers are seconded to the museum for a period of a term or a year. Whatever method is adopted, it is important that the teachers whose pupils are to visit the museum, should be 'briefed'. This may be done by holding a teachers' meeting at the beginning of the year, and by providing the teachers with a short, specially prepared guide to the collections.

With regard to school arrangements, the following may be noted:

(*a*) In order to make good use of the museum class visits must be carefully organized. Even where the distance to be travelled is small there is some loss of time. Thus the 'museum period' must, like most practical periods, be longer than the ordinary time-table period. When long distances have to be travelled, visits are rarer and should last longer if they are to be worth while. This is unavoidable, but care is needed. Pupils, especially younger ones, soon become tired, and the museum visit fails to achieve its purpose if pupils are bored.

(*b*) There should be a sense of purpose about every visit. An aimless visit, merely to walk round a museum, is not likely to achieve very much; indeed it may quickly lead to boredom. Every visit should have a clearly defined aim, to be fully discussed beforehand. This orientation or briefing of pupils is essential, just as in the case of seeing a film or going out on a field trip.

The teacher himself should know the museum personally. He should pay a preliminary visit and discuss its purpose with the museum staff. In this way he may learn of special points of interest or even have special material made available. It is also important that the teacher should know not only what he wants his pupils to do, but how long it is likely to take them to do it. To expect too much leads to frustration; to expect too little leads to boredom or lack of discipline. On the other hand, once pupils have some idea of how to use the museum, it should be possible for them to follow up their own interests.

The pupils need not all be concerned with the same topic. Indeed, to have several topics on hand reduces congestion round the show cases. Every pupil should have materials for making records: notebook, pencils, crayons, etc. Each pupil must know exactly what he is expected to do. Moreover, his particular task should not be assigned to him by the teacher, but whenever possible, be determined and selected by the pupil himself. Interest is an incentive to learning.

(*c*) Follow-up work is just as important as preparation for the visit. It may start as a discussion about the visit. 'What did you see?' 'Did you find a specimen of so and so?' 'Have you solved your problem?' 'Have any new problems arisen?' This may be followed by some sort of collective reporting, or by the exhibiting of all the notes and drawings made. In this way each pupil benefits from the work of others, as well as from his own work, and may develop a sense of co-operative responsibility.

(*d*) Although most of the work done by pupils in the museum is in organized parties, every effort should be made to encourage individual visits in leisure time. For this reason we have to make sure that pupils and museum staff know each other, and that the staff members are ready to help the child who comes in alone. In some museums 'junior member's tickets' are issued to school pupils as a kind of pass to the museum's services. If a ticket includes some special privilege it also comes to be a guarantee of good conduct.

Finally, if pupils have no appreciation of the value of the public museum, every effort should be made to stimulate their interest. It may be possible to arrange a meeting of teachers, pupils, parents and members of the museum staff.

The mobile museum

Considerable success has been achieved in some countries by the use of mobile museums. These are usually motor-vans specially fitted up for the purpose. They have two great advantages over the collections sent out to schools in boxes. Firstly, they are able to show a much larger exhibition. Secondly, they may often be accompanied by an expert museum worker. They are, of course, costly.

In some areas it has been found possible to use both methods of serving the schools. The mobile unit may then be the means of distributing the boxes.

The school museum

Much that has been said about the public museum applies equally to the school museum. There are, however, further points to be considered. These go beyond the differences of size, financial resources, etc. We have to think about the function and use of the school museum. These are far narrower than those of the public museum, as they are restricted in range of subjects as well as in the level of the work to be done. So far as use is concerned, the school museum should be a more intimate part of the school's teaching aids. Moreover, the school museum is under the direct and complete control of the teacher, so that it can be planned and operated with a greater regard to the needs of pupils.

In general the function of a school museum is to provide concrete illustrations of the learning to be found in the library. It should help to give abstract theory a basis of reality. It is with this major theme in mind that the school museum should be developed. At the same time we should remember local conditions and needs. Thus any suggestions made here are intended to be modified according to the position and needs of the teacher's own school.

We have to decide, first of all, whether to have one central school museum or separate departmental ones. The decision to have a central museum is most easily made when a new school is being built, but it is seldom taken. When the decision is taken after the buildings are completed, we have to make the best of whatever accommodation is available. A large class-room or a small hall is essential, and there should also be a small preparation room or workshop.

A central museum has various advantages. Supervision and organization are easier and tend to be better, especially if a full-time or even part-time curator has sole charge. The relationships between different branches of knowledge are more readily shown and this helps pupils' understanding. It also permits of uniformity of technique, thus reducing cost and time. Further, it tends to lead to a better 'balance' in the attention given to the various subjects.

Many experienced teachers, however, believe it better to have their own sectional museums in their own departments. As experts in a particular subject, they feel better qualified to take charge of the material. A single curator has to deal with many subjects, without the team of assistants available in a public museum. This objection may be met by suggesting that the whole staff could co-operate, as is done in many schools. It is, however, true that a sectional museum, in a single department, offers more opportunity for work, especially for quick reference when there is unexpected need. The departmental museum undoubtedly gives a sense of personal possession, stimulating interest and encouraging pupils to take an active part.

A school biology museum

In setting up a school biology museum the interest of the pupils should be sought from the start. The idea should be talked over with all the classes, and everybody invited to make suggestions.

The younger pupils probably think only of collections, but older ones are able to think in wider terms. All ideas should be encouraged. The teacher should do all he can to suggest the value of a functional museum, to deal with the important basic ideas in biology and emphasize universals rather than details. As discussion proceeds and ideas clarify, the suggestions offered may be written down to form a list of proposed contents. These may be arranged in three major sections:

Section A. General biological topics

Parasitism
Symbiosis
Commensalism
Mimicry
Camouflage
Coloration
Plant pests
Adaptation
Homology
Analogy
Metamorphosis
Variation
Genetics
Ecology
Distribution
Evolution

Section B. Zoological topics

The classification of animals
Characteristics of the major orders
The vertebrate skeleton
The vertebrate skull
Dentition
Evolution of the brain
Embryology
Fossil animals
The evolution of man

Section C. Botanical topics

The major plant groups
The monocotyledons
The dicotyledons
Plant structure
Floral structure
Seed dispersal
Plant distribution
Economic botany
Fossil plants
Living plants

These lists were actually prepared after discussions between teacher and classes in a particular school. They were used as the basis of a departmental biology museum. After preparing the lists, each subject or topic was taken over by a boy, or a group of boys, and a more detailed plan was prepared to show what it was intended to include. The next step was to decide what materials were needed, from where they could be obtained, and so on. The work was shared between pupils according to special interest and abilities. Boys interested in photography undertook to take photographs. One boy, interested in maps, made all the maps which were required. In this way each pupil was able to make his most effective contribution. All pupils learned a great deal of biology while building up the various collections.

In setting up the actual exhibits it is desirable to have a uniform plan for lettering, labels, colours and so on. This should be worked out before the practical work begins. An effective museum label is legible, simple and not overloaded with information. As the users of a school biology museum are pupils, with access to books, they are in a different position from the users of a public museum. Moreover, the school museum must not only provide information, but should pose problems. It must be a challenge to thought. This is possible only when its functions are considered in some detail.

Using the museum as a teaching aid. A school biology museum should be used not only by pupils who are actually studying biology, but also by those who are not. In other words, even a school museum, a specialized centre, should make a contribution to general education in the society having access to it. The needs of the two groups of pupils are different. For the non-specialist the material must be labelled and arranged so that it can be quickly understood. In particular it must show what biology is and why it is important. For this reason there must be an introduction, preceding examination of the groups of exhibits under the different topic headings.

Each teacher must consider what form this introduction should take. There are two main methods of approach:

(*a*) A *direct* approach based on a series of positive statements, for example:

Biology is the study of living things.
Living things may be divided into Plants and Animals.
Plants are characterized by....................
Plants are divided into groups..................

(*b*) A *problem* approach, for example:

Biologists study living things.
What are living things?
How do they differ from non-living things?
What are the basic problems of living?
Getting food?
Being protected?
Breathing? etc.

This introductory material may consist of a series of charts and pictures arranged to show the major fields of biological study in very broad outline. It should direct attention to the more complete general collections. Above all, it should clarify the essential relationships, however simple the method.

The more formal use of the museum is for pupils who are studying biology. There are three ways in which the museum may help.

(1) *For acquiring new knowledge.* (*a*) For instance, in studying the vertebrates pupils need to gain knowledge about skulls of various types. They should start by a general talk, with demonstration, upon certain broad principles of structure: cranial box, sense capsules and jaw apparatus. Next should come a detailed examination of a series of types. Thus pupils may be sent to the museum with a particular assignment such as:

'Examine the skulls of dogfish, frog and rabbit.
Make a large sketch of each.
Make a list of their major resemblances and differences.
Make a diagram to show the main parts of the skull.'

(*b*) Success in the carrying out of field-work of all kinds depends upon careful preparation. Thus, before visiting a particular plant habitat the herbarium may be used through suitable assignments, for example:

'(*i*) Examine the herbarium collection of hydrophytic plants. Make brief notes and rough sketches of the major types. This will help you to identify the plants when you visit a special locality next week.'

'(*ii*) Examine the school pond, vivarium and aquarium and find out if any living specimens of these plants are present.' (It should be noted that these instructions are based on the idea that herbarium specimens have been arranged in two series, one with a systematic [taxonomic] basis, and one with a functional [ecological] basis.)

The relationship between the museum, the garden, the vivarium and the aquarium is also stressed. (References to these are made in Chapter VI.) *All* must be used, to emphasize the properties of living organisms as well as those of dead specimens.

Similarly, when using the museum, reference should be made to the collections of photographs, film-strips and so on, to give the widest possible experience.

(2) *For rearranging old knowledge.* The process of learning often includes seeing new relationships, looking at what is already known in new ways. The museum should be used to encourage this. An example may be taken from the study of evolution, the pupil's knowledge of which is based upon some familiarity with past life forms. To emphasize the fact that evolution is a continuing process the following assignment may be given:

'Examine the fossil materials on display and prepare a list of existing animals and plants which might be used to illustrate the fundamental idea of evolution.'

(3) *For revision.* Revision is a necessary part of the learning process in school, but it is often little more than unrewarding drudgery. This is because neither its function nor method have received sufficient thought. It has become mechanical and passive largely because the pupil is turning over the pages of a notebook, instead of engaging in constructive thinking.

Proper use of the museum may bring about some improve-

ment, especially by presenting problems, or through the setting of an activity. Thus such assignments as these may be set.
'Make a list of the chief relations between dental structure and feeding habits.
Find out how many of these relationships are demonstrated in the biology museum.
Suggest alternative examples to replace those in use.
Make a list of materials which you would use to illustrate any relationships which are not shown in the museum.'

Museum and library

In much of the more advanced work in the museum, constant reference to books is essential. This is one reason for having a departmental library, as well as a departmental museum. In some schools library and museum are combined. In others they are arranged next door to each other.

In order to permit the use of books in the museum it is desirable to have tables and seating for reading. These should be large enough to allow the use of a drawing-board and drawing-book by those engaged in making illustrations.

Museum and local records

It is useful to devote part of the museum to special studies and exhibitions of local biology: common flowers, local animals, etc. In addition to preserved specimens, living things, especially flowers and plants, should be shown. There should also be provision for filing the records of local field-studies and for showing distribution maps and photographs. It is extremely important to preserve such data from year to year, not only to get a time-perspective, but to demonstrate variation in the sequence and periodicity of natural events, and to show how knowledge is built up by continuous effort.

Accommodation

A special room for the museum is the ideal arrangement, but there is seldom enough space for this to be possible. However, a spare class-room or even a small store-room may be made available. Failing this, the museum exhibits must be arranged on the walls of a class-room, a laboratory, or even a corridor.

Whatever space is to be used, it should be carefully surveyed and a rough sketch made showing dimensions. This is used for planning the layout, deciding how much space may be given to various topics, and so on. With foresight and ingenuity a great deal can be accomplished in very little space. The claim that there is no space available should seldom be allowed to prevent the setting up of some sort of exhibition.

Display equipment

There is no need to have elaborate display cases, but four basic provisions are required:

(*a*) Space for posters, charts and diagrams. These may be on the walls and doors of rooms and cupboards, or on special display stands, made from wooden strips. The carpentry classes may help, but there is no reason why the biologists should not do their own constructive work (see Fig. 28).

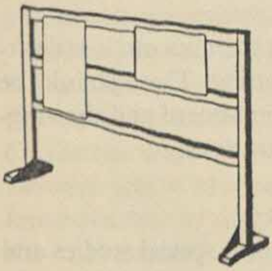

FIGURE 28.—A portable display-stand. Use wooden strips 2 in. × 1 in. in section for the frame and use triangular plywood pieces to give extra support to the upright pillars. The horizontal parts should be so spaced as to take a standard size of paper (e.g. Imperial) in both horizontal and vertical positions

(*b*) Shelving is needed for storage and exhibition purposes. It is usually convenient to have the lower shelves flat but the higher ones tilted, so that the outer edge is a little lower than the back. The height of the shelves should be related to the height of pupils, not of the staff. A narrow beading on the front edge prevents specimens falling off. If possible the shelving should be adjustable, so that the distance between shelves may be varied to meet new needs, which may arise through the introduction of new specimens or from rearrangement of exhibits.

(*c*) Display cases with glass tops are useful, as they allow more complete examination and protection of specimens than is usually possible on shelves. Such cases, however, are costly to buy and not very easily made by the amateur. They can sometimes be bought second-hand, even from shops where they have been used to display confectionery, trade articles, etc.

(*d*) Drawers are sometimes needed for specimens likely to suffer from continuous exposure to light. They are almost essential for storage purposes. These, too, are expensive and difficult to make, but they also may be obtained from chance sources.

Apart from purchasing or making this kind of museum furniture, it is sometimes possible to convert old furniture for a new purpose. Even a tea-chest or packing-case may be converted to new uses. An objection often raised is that the wood is rough and unsightly. To dismantle such boxes, plane the wood and rebuild, is laborious and often difficult because of cracking. It is often possible to improve the surfaces by sand-papering and then painting. An alternative is to line and cover such boxes with paper or cloth, which may be renewed when necessary.

Preparation of museum material

Although students who follow university courses in the biological sciences usually learn something of slide-making techniques, they are seldom offered an adequate training in museum methods. While these are somewhat specialized, and often complex, there are a few simple suggestions of value to those who wish to build up a school museum.

Skeletal material. The first step is to dissect away as much flesh as possible. It is often convenient to disarticulate the limbs from the main axis and thereafter deal with each limb separately. In the next stage, the maceration of the flesh, it is often desirable to avoid the complete removal of the tendons and ligaments which, when left in place, will dry and thus hold together the smaller elements. It is essential to prevent maceration from going too far in delicate skeletons, such as that of the frog or toad.

Maceration may be carried out by any of the following methods:

(*a*) Standing the specimen in cold water until the rotting flesh may be removed easily.

(*b*) Letting the specimen simmer slowly in hot water and then scraping or brushing the flesh off.

(*c*) Simmering in a solution made up of a gallon of water, half an ounce of sodium sulphide and two ounces of pancreatin.

(*d*) Placing the skeletal material in a flat tray with a loosely fitting cover, allowing ants to enter, but keeping out other animals.

Flesh may be removed by means of scalpels, a stiff brush or a steam jet.

After the flesh is removed the bones should be dried and bleached in the sun. A quicker method is to soak the bones in a fat solvent (such as xylol) and then air dry; or to soak first in alcohol and then a bleacher, such as hydrogen peroxide, and dry.

Mounting a skeleton. In the case of a small skeleton, such as a frog, the vertebrae are threaded on a match-stick, the skull glued into position, then the pelvic and pectoral girdles and finally the limbs. The various parts should be correctly arranged to give a natural position.

A larger skeleton, such as a bird or small mammal, is dealt with on the same principal, though different methods are used. Ordinary gluing is not satisfactory. It is better to drill holes in the bones in suitable places and fix them together with fine wire passed through the holes. The vertebrae should be threaded on to a stiff wire which has been bent to a proper curve. At the front end a cork is fixed to carry the skull. Two stiff vertical wires, with their lower ends firmly stuck in a board, are used to support the column. The girdles and limbs are fixed in position by wire.

The skeleton of the dogfish or ray requires careful handling and maceration must *not* be complete, thus preventing the elements from falling apart (especially the branchial skeleton). Such skeletons should be attached to a flat sheet of celluloid or glass and then preserved in a bottle of suitable fluid.

Injected specimens. For demonstration purposes it is useful to have a few specimens in which the blood vascular system is injected. Injection should if possible be carried out immediately after death. Small animals may be injected with a glass pipette and a rubber teat or with a hypodermic needle. Larger carcases are injected under a gravity feed.

The vessels should be washed out with warm normal salt solution, or if death occurred some hours before, with warm 0·5 per cent sodium citrate.

Injection should be carried out as slowly as possible and the injection nozzle should not have sharp edges and should be entered into a suitable vessel through a small incision. A light ligature keeps it in place.

Suitable injection media are as follows:

(*a*) Gelatine. Sheet gelatine is melted in warm water and a suitable water-soluble dye (usually red for arteries and blue for veins) is added. The medium must be kept hot while injecting and the carcase immersed in warm water.

(*b*) Rubber latex. This may be either 'prepared' or collected straight from the tree. By adding alkali the latex remains liquid. When injection is complete, the carcase is put in an acidified formalin solution to solidify the latex.

(*c*) Plaster of Paris. This is made up as a very watery suspension. Its disadvantages are that it is difficult to inject in that it becomes brittle.

In *single* injection either veins or arteries are injected; in *double* injection both are injected. Mixture of the two colours is usually prevented by the terminal capillary pressures. In some cases ligatures may be needed.

The locations for injection are as follows:

(*i*) Dogfish, ray, skate, etc.

Efferent arterial system: through the caudal artery after severing the tail; plugged by match after injecting.

Afferent system: insert nozzle through ventricle into conus.

Visceral arteries: through caudal artery.

Visceral veins: through caudal vein.

Venous sinus: through sinus venosus.

(*ii*) Frog or toad.

Arterial system: through the ventricle.

Venous system: through sinus venosus.
(*iii*) Rabbit or rat.
(Drain all blood by severing vessels in hind leg.)
Arterial system: through base of aortic arch.
Venous system: through sinus venosus.

Preserving media

(1) For animal specimens:

(*a*) 70 per cent alcohol.
(*b*) 5 per cent formalin.
(*c*) alcohol—formalin—glycerin.

50 per cent alcohol	90 parts
3 per cent formalin	10 parts

about 2 drops of glycerine per c.c. of solution.

(2) For plant specimens:

(*a*)	water	6 parts
	95 per cent alcohol	3 parts
	formalin	1 part
(*b*)	commercial formalin	5 parts
	glacial acetic acid	5 parts
	50 per cent alcohol	90 parts

(*c*) this requires two solutions:

(i)	5 per cent copper sulphate	
(ii)	commercial concentrated sulphuric acid	16 c.c.
	sodium sulphite anhydrous	21 gm.
	water	1000 c.c.

Place the specimen in (i) for 24 hours and then preserve in (ii). This method is fairly effective in preserving plant colours.

Herbarium specimens. It is useful to have collections of dried herbarium specimens arranged in two series. One set should be arranged in systematic groups (families) and the other in ecological groups, showing the plants of marshland, sea-shore, etc.

When collecting specimens it is important to take a complete plant, root, shoot, flowers and seeds, though this is not easy where the plant is very large or the root big and solid—as in a tap root.

Each plant should be arranged in such a manner as to show all its parts clearly, placed between sheets of paper and pressed with a weight. Special fluffless drying paper may be bought for drying. Ordinary blotting paper may be used, and even sheets of newspaper are satisfactory. A drawing board or piece of plywood should be placed on top of the pile and the weight, a few heavy books for example, distributed evenly on this.

When perfectly dry each plant should be mounted on a sheet of paper. Cartridge drawing paper is good, but expensive. The cheapest alternative is unused newsprint bought as 'ends' from a newspaper press.

The plant should be fixed in position by a few narrow strips of paper gummed across the stem and leaves.

Each sheet should carry full details: family group, genus, species, location from which the plant came and date of collection.

Collections of such plants may be stored in a large folder made from cardboard and linen.

Two precautions are essential:

(*a*) *Against damp*, by storing in a dry place and frequently opening the folders to allow adequate ventilation.

(*b*) *Against insects*, by lightly dusting the sheets with a very small amount of powdered borax, or a proprietary DDT insecticide.

Special herbarium collections should be made to show local agricultural problems. These should deal with local weed pests, local varieties of important crops, etc. It is important to link up biology teaching with local agriculture, so these special collections should be as complete as possible. Displays may include photographs, records from local field yields, and information from the local agricultural officer such as pamphlets, circulars, etc.

Insect collections. Apart from the study of standard type specimens, such as the cockroach, attention should be given to the insect as a significant factor in local life. Thus there should be collections to show local insect pests which attack crops or carry disease. For each species in the collections there should be:

(*a*) Specimens of all stages of the life history.
(*b*) Large-scale diagrams of the various stages of life history.
(*c*) A diagrammatic analysis of the life history.
(*d*) Information on methods of controlling the pest.

Large insects, such as flies or moths, may be killed in a killing jar and mounted on a pin. A killing bottle is made by grinding a little cyanide of potassium to powder and placing it in the bottom of a wide-necked bottle. This is followed by a layer of sawdust, and finally plaster of Paris is poured in to a depth of about half an inch. The bottle should have a glass or rubber stopper and should be handled with great care. An alternative and less dangerous method is to use a wide-necked jar with a cork bung. A hole is bored through the bung and a cotton-wool plug inserted. The insect is put in the jar and a few drops of chloroform are poured on to the cotton-wool.

When dead, the insect is removed from the jar, a pin is thrust through the thorax and the specimen is placed on a setting board with the wings spread out. When dry it is removed and placed in a cabinet or display box. The pins should be of brass rather than iron, which rusts. Commercial dealers supply special entomological pins which are black and rustless.

In museum work it is sometimes necessary to re-set an insect. To do this it must first be 'relaxed' or softened by keeping it in a moist atmosphere until the wings and legs may be moved without danger of breaking them.

For displaying insects only shallow boxes are needed. They may be made from soft wood, with a glass top held in place by a strip of adhesive paper. Small boxes, suitable for showing a single life history, may be made from cardboard with a cellophane top.

A number of match-box drawers may be gummed to a strong cardboard base. The specimens may then be fixed in the drawers. The whole is then covered by a glass sheet, fastened down by cellophane tape or 'passe partout'.

APPENDIX A

LIST OF APPARATUS FOR THE TEACHING OF BIOLOGY UP TO (FOR EXAMPLE) THE GENERAL CERTIFICATE OF EDUCATION ('A' LEVEL)

This list of equipment is a modification of the standardized list of biology equipment used by the Ministry of Education in Ceylon. It represents those items considered absolutely essential and is thus a minimum list for a well-equipped laboratory. The list refers to a group of 20 pupils. In a few cases alternative figures in brackets show a more desirable number.

Extensions to this list must depend upon financial resources and special interests.

Specifications are given in a few cases in order to indicate the kind of apparatus and its potentialities.

GROUP I—OBSERVATIONAL EQUIPMENT

No. or Qty.	Item	Specifications
1 (5–10)	Auxanometer	Simple design. Vertical metal rod on heavy metal base with arm on adjustable boss. Pulley at free end of arm with pointer rotating to read on calibrated scale 0–01 inch divisions.
1	Balance, student's	Lacquered brass graduated beam, agate knife-edges and arrestment device; mounted on polished hardwood base with plumb-bob and levelling screws; case fitted with a counter-balanced sliding front panel. Maximum load 250 gm. Sensitivity 5 mgm.
1	Cylinders, graduated	Heat resistant glass, hexagonal base; 200 c.c. × 1 c.c.
1	Cylinders, graduated	Heat resistant glass, hexagonal base; 1000 c.c. × 2 c.c.
1	Cylinders, graduated	Heat resistant glass, hexagonal base; 10 c.c. × ½ c.c.
20	Hand lens	Double lens ×10; field diameter 25 mm. approx. folding into plastic mount.
1	Manometer	One arm vertical open, the other connected to a wider tube, short and turned out and down, expanded end for connection to stem. Scale on vertical arm graduated in mm.
10	Microscope, monocular	Student's quality. Massively built. Stand inclinable through 90° from vertical to horizontal. Adjustable draw tube. Rack and pinion focussing with separate coarse and fine adjustment. Double nose piece, rotating with constant approx. focus. Two objectives, achromatic, focal length ⅙″ and ⅔″. Square stage with stage clips. Rack focus sub-stage with removable

No. or Qty.	Item	Specifications
		condenser, iris diaphragm and filter slot. Planoconcave mirror in gimbal mount for use with daylight. Daylight correction blue filter. Two objectives: Huyghenian, ×10 and ×4. Screw-top metal cases for objectives and eyepieces. Wooden case with carrying handle, lock and key and carrying slides for optical elements.
10	Microscope, dissecting	Student's quality. Stand of wood or plastic moulding with inclined arm-rests and horizontal centre stage of area 3″ × 2″. Removable glass stage-plate and removable mirror reflector set at 45°. Double lens 1″ diameter minimum and × 10 magnification, with screw focus mount, on swinging arm, on vertical pillar in sliding mount for coarse focus. (*N.B.* Flat base stand without arm rests not considered suitable.)
1	Microscope, teacher's demonstration	High quality; massive stand inclinable through 90° from vertical to horizontal. Adjustable draw tube, calibrated. Rack and pinion focus; separate adjustment controls. Quadruple nose piece, rotating four parfocal (approximate) objectives; $\frac{1}{12}$″ oil immersion apochromatic; $\frac{1}{6}$″, $\frac{2}{3}$″ and 1″ dry achromatic. Square stage, mechanical, calibrated; rack focus sub-stage with swing-out removable condenser, iris diaphragm and filter slot. Planoconcave mirror in gimbal mount. Blue correction filter. Eyepiece ×4 with adjustable field pointer. Eyepiece graduated disc and stage graticule for measuring. Screw-top metal cases for objectives and eyepieces in sliding trays. Wooden case with handle, lock and key.
1	Pipette	Heat resistant glass, 25 c.c., student's type.
1	Potometer	Thoday's pattern. Horizontal glass potometer tube with vertical open end for plant; side arm for thistle funnel, rubber tube and screw clamp. Other end of potometer tube with rubber connector to 1 mm. capillary tube with millimeter scale. Wooden base and vertical backboard.
1	Respiroscope	Ganong's pattern. Glass bulb with ground-in stopper with air hole, closed by turning stopper. Descending limb graduated and drawn to tubulure for rubber manometer tube at bottom end. Total volume 102 ml. above liquid level marked zero. Graduated in ml. Rubber connector and side tube to complete manometer. Double clamp and stand.
12	Thermometers	– 10° C. to 110° C, ×1° C. In wooden case.
1	Gram weights	Brass weights of the usual screw knob type, in polished hardwood case with lid, complete with glass cover for fractional weights and pair of nylon-tipped forceps, Set: 10 mgm., 2 × 20 mgm., 50 mgm., 100 mgm., 2 × 200 mgm., 500 mgm., 1 gm., 2 × 2 gm., 5 gm., 10 gm., 2 × 20 gm., 50 gm., 100 gm. Weights should conform to the National Bureau of Standards.
1	Gram weights	Brass weights of the usual screw knob type, in polished hardwood case with lid, complete with glass cover for fractional weights and pair of nylon-tipped forceps. Set: 1 gm., 2 × 2 gm., 10 gm., 2 × 20 gm., 50 gm. Weights should conform to the National Bureau of Standards.

GROUP II—CONTROL AIDS

No. or Qty.	Item	Specifications
1	Burners	Bunsen type, heavy base, brass tube, internal diam. $\frac{7}{16}''$, air regulator, supply pipe and jets for petrol air gas supply with gas and air adjustments.*
1	Klinostat	Clockwork with 8-day movement. Horizontal axis. Holder adjustable to take plant pots 6″ deep by 3″ base diameter, with taper sides to 4″ top diameter (approx.). Holder interchangeable with flat disc with cork surface.
1	Light screen, botanical	Box form with mounting adjustable for height and angle; box about 6″ × 4″ and 1½″ deep, divided into two compartments, excluding light and providing free access of air to the underside of the leaf; with glass filters; red, yellow, green, blue and violet.

* This proposal was made for schools lacking a gas supply. Where this is available on benches more bunsen burners would be useful.

GROUP III—MATERIALS (CHEMICALS)

250 gm. Acetic acid	Glacial ('Analar' quality)
500 gm. Acetone	
100 gm. Aluminium ammonium sulphate	'Analar' quality
250 gm. Aluminium oxide	For chromatographic analysis
1 Kgm. Ammonium hydroxide	(.880)
10 gm. Aniline blue	Spirit soluble
250 gm. Aniline sulphate	
250 gm. Barium hydroxide	'Analar' quality
10 gm. Borax-carmine	'Crenache'
5 gm. Bromo-thymol blue	
500 gm. Calcium chloride	Fused granular 10–14 mesh
250 gm. Calcium phosphate	Precipitated
100 gm. Calcium sulphate	Hydrated—'Analar' quality
100 gm. Canada balsam	Dried and dissolved in Xylene—thick
250 gm. Carbon Tetrachloride	'Analar' quality
10 gm. Carmine	
25 gm. Cedar wood oil	
100 gm. Chloral hydrate	
500 gm. Chloroform	
100 gm. Chlor-zinc-iodine	Schultze's solution
250 gm. Clove oil	Redistilled and dried
25 gm. Cobalt chloride	'Analar' quality
250 gm. Copper sulphate	'Analar' quality
25 gm. Diastase	
10 gm. Eosin	Spirit soluble
5 gm. Eosin	Water soluble
250 gm. Ether	
1 W.Qt. Ethyl alcohol	Absolute
250 gm. Ferric chloride	Hydrated 'Analar' quality
500 gm. Ferrous phosphate	About 50% $Fe_3(PO_4)_2,8H_2O$
3 W.Qt. Formaldehyde	37–41% solution
500 gm. Fuchsin acid	
100 gm. Glucose	'Analar' quality
250 gm. Glycerine	Jelly
10 gm. Haemotoxylin	Delafield's
1 Kgm. Hydrochloric acid	About 36% Sp. gr. 1·18
100 gm. Invertase	

No. or Qty.	Item	Specifications
25 gm.	Iodine	'Analar' quality
1 W.Qt.	Isoprophyl	Ordinary
10 gm.	Leishmann's stain	
250 gm.	Magnesium sulphate	'Analar' quality
1 Kgm.	Mercury	
250 gm.	Methyl alcohol	Special quality
25 gm.	Methyl blue	
500 ml.	Nitric acid	Sp. gr. 1·42, lead not exceeding 0·005 p.p.m.
1 lb.	Paraffin wax	'Clearing-point' 60° C.
25 gm.	Potassium hydroxide	Pellets
20 gm.	Potassium iodide	
250 gm.	Potassium nitrate	'Analar' quality
25 gm.	Pyrogallol	Resublimed
2 W.Qt.	Rectified spirit	
10 gm.	Safranine	Water and alcohol soluble
1 Kgm.	Sodium bicarbonate	
250 gm.	Sodium borate	'Analar' quality
500 gm.	Sodium chloride	
250 gm.	Sodium hydroxide	Pellets
25 gm.	Sodium potassium tartrate	'Analar' quality
1 Kgm.	Sulphuric acid	About 98%
250 gm.	Sucrose	'Analar' quality
25 ml.	Sudan III	Alcholic solutions
25 ml.	Sudan IV	Gross's solution
500 gm.	Xylene	Sulphur free

GROUP IV—TEACHING AIDS

1 each	Dissected specimens	Mounted in solid plastic to permit handling and all-round observation. *Helix pomatia* *Lacerta* sp. *Marchantia* (in Bioplast) *Mus rattus* *Passer domesticus* *Phaseolus* (in Bioplast) *Polytrichum* (in Bioplast) *Rana* sp. *Salamander* sp. *Zea Mays* (in Bioplast)
1 each	Models (*i*) *Animal*	Models on separate stands to show main stages in: (*a*) Mitosis (at least 8 models) in relief (*b*) Meiosis (at least 8 models) in relief (*c*) Embryology of frog (at least 12 from egg to tadpole, some complete, some section, all in three dimensions).
1 each	(*ii*) *Human Anatomy*	Eye—enlarged × 5, dissectible to show main structures. Ear—enlarged × 5, dissectible to show structural details of inner ear. Teeth—1 canine, showing longitudinal section; 1 molar (2 roots) showing longitudinal section. Heart—× 2, dissectible, to show internal structure, nerves, vessels, chordinae. Brain—natural size, dissectible in 4 parts. Cranium and neck in half-section, natural size; brain, spinal column, nerves, blood vessels, oral cavity structures, nasal structure.

No. or Qty.	Item	Specifications
		Jaw, lower—× 3; dentition, vessels, nerves, etc.
		Skin—3-dimensional, all details, about 10″ × 12″ × 12″.
		Skeleton, plastic, half-size.
		Above models in plastic or rubber, preferably each in protective display box with transparent cover.
1 each	(*iii*) *Plant*	3-dimensional models with face section in transverse, longitudinal and tangential planes. If possible with conducting vessels and vascular tubes either hollow or with deep relief, as well as channel-like. (In longitudinal and tangential sections.)
		(*a*) dicotyledonous stem
		(*b*) dicotyledonous root
		(*c*) monocotyledonous stem
		(*d*) monocotyledonous root
		(*e*) typical leaf structure with petiole and with leaf in transverse section to show epidermis, stomata, pallisade cells and spongy layers, with details of vascular bundles.
1 each	Skeletal material	Prepared mounted unlabelled skeletons of:
		(*a*) Dog-fish (in jar with glycerine preservative)
		(*b*) Bony fish (e.g. Perch, Carp)—dry mounted
		(*c*) Bull frog—dry mounted
		(*d*) Newt (in jar)
		(*e*) Lizard—dry mounted
		(*f*) Bird—dry mounted
		(*g*) Cat—dry mounted.
	Slides, microscopic (prepared) (*i*) *Botany*	Set of the following slides in box with index:
1		*Chlamydomonas*—entire
3		*Cycas* —T.S. stem
3		,, —T.S. root
3		,, —T.S. petiole apex
3		,, —T.S. petiole near apex
3		,, —T.S. petiole base
2		,, —T.S. microsporophyll
1		,, —V.S. pollen chamber
1		,, —L.S. archegonia
6		*Dracaena* —T.S. stem
2		,, —T.S. root
3		*Lilium* —T.S. flower bud
1		*Erotium* —V.S. perithecia
3		*Marchantia* —T.S. thallus
3		,, —V.S. anthridiophore
3		,, —V.S. archegoniophore with archegonia
3		,, —V.S. archegoniophore with capsules
3		*Mucor* —Hyphae with zygospores
3		*Nephrolepis* —T.S. rhizome
3		,, —T.S. root
3		,, —T.S. stolon
3		,, —T.S. leaf with sori
1		,, —T.S. prothallus with antheridia
1		,, —T.S. prothallus with archegonia
3		*Oedogonium* —Oogonia

No. or Qty.	Item	Specifications
1	*Oedogonium*	—Androsporangia
2	,,	—Nannandria
3	*Onion*	—Root apex showing cell division
3	*Pinus*	—T.S. stem
3	,,	—Wood—T.S., R.L.S., T.L.S.
2	,,	—T.S. root
2	,,	—L.S. staminate strobilus
1	,,	—L.S. ovule
3	*Pogonatum*	—T.S. stem
3	,,	—T.S. leaf
3	,,	—L.S. perichaestium
2	,,	—L.S. archegonia
3	,,	—L.S. capsule
3	,,	—T.S. capsule
3	*Selaginella*	—T.S. stem
3	,,	—T.S. rhizophore
3	,,	—T.S. root
3	,,	—L.S. strobilus
1	*Spirogyra*	—Conjugation and zygospores
6	*Vanda*	—T.S. root
6	*Zea Mays*	—T.S. stem
3	,,	—L.S. stem.
	(*ii*) *Zoology*	Set of the following slides in box with index:
3	Areolar tissue	
3	Bone T.S.	
1	Bone L.S.	
3	Cartilage T.S.	
1	Chick embryo	—1 day old
1	,, ,,	—2 days old
1	,, ,,	—5 days old
3	T.S. of trunk	—chick embryo—1 day old
3	T.S. of trunk	—chick embryo—2 days old
3	T.S. of trunk	—chick embryo—3 days old
3	Earth-worm	—L.S. anterior region
3	,,	—T.S. pharynx
3	,,	—T.S. gizzard
6	,,	—T.S. intestine
3	,,	—Through testis
	,,	—T.S. oesophagus
3	Hydra	—Entire
3	,,	—T.S.
3	,,	—L.S.
	,,	—T.S. with gonads
6	Mosquito	—Entire
3	,,	—Larva
3	,,	—Pupa
3	Liver fluke	—Entire
3	,, ,,	—T.S.
1	Paramecium	—Asexual reproduction
1	Plasmodium	—Trophozoites
3	Rat	—V.S. skin
6	,,	—V.S. skin
6	,,	—T.S. intestine
3	,,	—V.S. wall of stomach
3	,,	—T.S. kidney
3	,,	—T.S. testis
3	,,	—L.S. ovary

No. or Qty.	Item	Specifications
3	Rat	—T.S. liver
1	,,	—T.S. pancreas
3	,,	—T.S. lung
1	,,	—L.S. cardiac muscle
1	,,	—T.S. salivary gland
3	Tadpole	—L.S. with external gills
3	,,	—T.S. with external gills
3	,,	—T.S. with internal gills
6	Tape worm	—Entire proglottis
3	,, ,,	—T.S.
	,, ,,	—Anterior region
6	Toad	—T.S. intestine
6	,,	—T.S. stomach
6	,,	—V.S. skin
3	,,	—T.S. kidney
3	,,	—T.S. testis
3	,,	—V.S. ovary
3	,,	—T.S. striped muscle
3	,,	—Bladder wall
3	,,	—T.S. lung

GROUP V—VARIOUS

3	Basins	Heat resistant glass, medium-walled, flat-bottomed, diam. 80 mm., height 40 mm.
4	Beakers	Heat resistant glass, short form, medium-walled, spouted 250 c.c.
1 (2)	Bell-jar	Heavy moulded glass, open at top, with tubulars and ground-in glass stopper, well ground flange at bottom, height about 12″ and internal diam. about 6″.
3	Bottles, gas-washing	Heat resistant glass, with stout necks, fitted with rubber stoppers carrying right-angle bent tubes, the ends formed and fire-polished, one of the tubes reaching down to the bottom of the vessel, capacity 250 c.c.; bent tubes approx. outer diam. 6–8 mm. Or similar bottle with ground-in glass stopper instead of rubber bung.
5 (10)	Bottles	Heat resistant glass, designed to contain Canada Balsam, 30 c.c. capacity.
6	Bottles	Heat resistant glass, wide-mouthed with bakelite screw caps, capacity 50 c.c.
6	Bottles	Heat resistant glass, extra wide-mouthed with bakelite screw caps, capacity 100 c.c.
6	Bottles	Heat resistant glass, wide-mouthed, with bakelite screw caps, capacity 250 c.c.
8	Bottles, reagent	Heat resistant glass, narrow-mouthed, dust-proof, with ground-in glass stopper, capacity 250 c.c.
1	Bottles, aspirator	Heat resistant heavy glass, cylindrical, heavy moulded at base, complete with ground-in glass stopper, capacity 10-litre.
77	Bottles, dropping	Ground-in slotted stopper, capacity 60 c.c.
2	Boss-heads	Metal, universal, with screw type wing-nuts to suit retort stands.
1	Brush, bottle	Galvanized wire handle.
20	Brushes, camel-hair	Length ½″, width 4 mm. approx. First quality.

No. or Qty.	Item	Specifications
2	Clamps	Metal, Universal, V-jaw, with rubber jaw sleeves.
2	Clips, Mohr's	Nickel-plated brass.
1	Cork-borers	Nickel-plated brass, with ejector, set of 7; 4–10 mm. diam.
1	Cork-borer sharpener	To suit above set of cork borers.
1¼ oz.	Cover glasses, microscope	Larger dimension being approx. ¾″ to 1″; thickness No. 1.
1	Cylinders, measuring	Heat resistant glass, spouted, hexagonal base; 1000 c.c. × 2 c.c.
1	Desiccator cupboard	Rectangular, glass sides and nickel-plated brass frames; so made that the door opens readily, on firm, well-designed hinges around a vertical axis, and closes to provide an air-tight enclosure. The catch should be robust and smooth in action.
20	Dishes, dissecting	White, enamelled-steel, 12″ × 7″, about 1½″ deep.
2	Dishes, dissecting	White, enamelled-steel, 14″ × 8″, about 2″ deep.
3	Flasks	Heat resistant glass, conical, medium-walled, narrow-mouthed, 250 c.c.
3	Flasks	Heat resistant glass, conical, medium-walled, narrow-mouthed, 500 c.c.
3	Flasks	Heat resistant glass, round, medium-walled, short-necked, flat-bottomed, narrow-mouthed, 500 c.c.
2	Flasks, graduated	Heat resistant glass, pear-shaped; long narrow neck; ground-in glass stopper; 500 c.c. student type.
2	Flasks, vacuum	Clear glass, cylindrical, height 20 cm., diam. 4 cm., capacity 250 c.c.
1	Flasks, (Buchner) filter	Heat resistant glass, thick-walled, 1 litre capacity.
1	Funnels	Heat resistant glass, plain, angle approx. 60°; 4″ diam.
1	Funnels	Heat resistant glass, plain, angle approx. 60°; 3″ diam.
1	Funnels, thistle	Heat resistant glass, plain stem; 30 cm. long
1	Funnels, separating	Pear shaped, medium-walled, ground-in stop-cock and stopper; 250 c.c.
20	Forceps	Surgical steel, fine point; 4½″ long.
1	Forceps	Surgical steel; 7″ long.
20	Forceps	Surgical steel, fine point; 3½″ long.
12	Jars, specimen	Moulded, clear, high-quality, colourless glass; rectangular; 10 × 12·5 × 6 cm.
6	Jars, specimen	Moulded, clear, high-quality, colourless glass; rectangular; 15 × 15 × 6 cm.
2	Jars, specimen	Moulded, clear, high-quality, colourless glass; rectangular; 20 × 20 × 10 cm.
6	Jars, specimen	Heat resistant glass, cylindrical, with ground-in stopper; height 10 cm., diam. 8 cm.
6	Jars, specimen	Heat resistant glass, cylindrical, with ground-in stopper; height 20 cm., diam. 6 cm.
3	Jars, specimen	Heat resistant glass, cylindrical, with ground-in stopper; height 10 cm., diam. 8 cm.
1	Knives, grafting	Folding, with handle.
1	Knives, ordinary	Large, with 10″ blade (e.g. Machette type).
1	Knives, pocket	Two blades, stainless steel, 3″ long approx.
1	Mortar and pestle	Porcelain, with spout. Mortar, glazed outside and partially inside; pestle glazed (except grinding surface). Capacity 75 c.c., diam. 9 cm.

No. or Qty.	Item	Specifications
40	Needles, dissecting	Medium gauge, fixed firmly in wooden handle, needle 2″ long approx.
8 prs.	Petri dishes	Diameter 10 cm.
1	Pot	Spun aluminium for transpiration experiments; diam. 3″ approx.
1	Razor	Surgical steel. One side flat, the other hollow ground.
20	Scalpels	All metal, surgical steel; cutting edge 25 mm.
20	Scalpels	All metal, surgical steel; cutting edge 40 mm.
20	Scissors	Surgical steel, pointed, 40 mm., cutting edge 120 mm.
20	Scissors	Surgical steel, pointed, 60 mm., cutting edge 120 mm.
1 set	Slides	Glass, blue, yellow, red and green, 2″ × 2″.
2 gross	Slides, microscope	3″ × 1″, ground edges. 1 to 1·2 mm. thickness
4	Stands, tripod	Single iron ring, with three threaded legs; 9″ high, ring diam. approx 4″ to 5″.
2	Stands, retort	Large, metal, rectangular base, approx. 6″ × 10″, with rods approx. 18″ × ⅜″ diam. vertical rod screwed to base plate, painted with high-quality anti-corrosive paint.
1	Syringe, injection	Anatomical, with brass barrel; 3 nozzles of 1 mm., 5 mm. and 2 mm. diam.; regulating tap; capacity 100 c.c.
4 doz.	Test-tubes	Heat resistant glass, medium-walled, 6″ × 1″ with rim.
20	Test-tube holders	Circular, strong spring clip with wooden handle for holding test-tubes ½″ to 1″ diam., both sizes inclusive.
2	Troughs	Heat resistant glass, circular, thick-walled ground edge, 20 cm. diam., 10 cm. high
6	U-tubes	Good quality clear glass, plain form; diam. 20 mm., 15 cm. long.
1	Vasculum	Metal, with adjustable strap, 18″ long approx.
72	Watch-glasses	Heat resistant glass, ground edges; diam. 10 cm.
10	Wire gauze	Iron wire, asbestos centres; 12½ cm. square.

APPENDIX B

I THE MICROSCOPE

INTRODUCTORY NOTE

The microscope, although mounted on a heavy stand, is a delicate precision instrument. Like all such instruments it must be used carefully if it is to remain efficient. If it is not in perfect condition it cannot give the service for which it was designed.

The following notes show how the microscope can be used efficiently and maintained in good condition.

STRUCTURE

The microscope consists essentially of three parts:

1. *The stand* which supports the whole apparatus and which permits the tube to be inclined.
2. *The stage* which supports the materials to be examined and the auxiliary optical system, consisting of mirror, condenser and diaphragm.
3. *The tube* which carries the main optical system: eyepiece at the top and objectives on the nose-piece at the bottom.

ASSEMBLY OF MICROSCOPE

Examine the microscope and identify the various parts. If it has to be assembled proceed as follows:

(*a*) If necessary, unscrew the retaining bolt found on the outside of the bottom of the microscope box.
(*b*) Open the door with the box upright, on a bench or table (away from the edge).
(*c*) Remove packing materials and slide out the microscope. Note that the lenses (objectives) and eyepieces are not in position.
(*d*) Slide out, in turn, the trays carrying objectives and eyepieces. Check each item against list and against table of magnifications.
(*e*) Note the two pairs of milled discs (wheels) one large and one small. These are for coarse and fine focussing respectively.

The focussing controls must be used with extreme care. Never force them in any way. Turn the larger wheel and note that it has an upper and lower limit of travel. If it is turned too far, in either direction, the rack and pinion may be damaged, and the tube may even fall off the stand.

Turn the smaller wheel and note that it gives a very fine adjustment and also has a fixed stop when turned forwards or back to the limit. Never force this adjustment in any way.

(*f*) Note how the eyepieces can be placed in the upper end of the tube. All the eyepiece-tubes are of the same diameter, to fit the microscope-tube. Each eyepiece has its magnifying power marked on it. If this is five times it will be engraved as ×5 (times 5), if ten times as ×10 (ten times) etc.

Always put the eyepiece in position carefully.

Remove the eyepieces and replace in their racks.

(*g*) Note that the objectives, though of different lengths, have a common diameter to the female screw. This is the S.M.S. (Standard Microscope Size of the Royal Microscopical Society, adopted as an International standard). Thus objectives are interchangeable.

Objectives also have their power engraved on the mounting, though this is given in terms of focal length (in inches or millimetres). The Numerical Aperture (N.A.) may also be engraved.

Screw the objectives into the nose piece and carefully rotate the nose piece being sure that the tube has been racked upwards to give sufficient clearance so that the objectives are not damaged by hitting the stage.

Remove the objectives and replace in their racks.

(*h*) Examine the stage and place the stage clips or slide clips in position.

(*j*) Examine the sub-stage auxiliaries. Note the mirror, mounted in gimbals, with one concave and one plane surface. Note the condenser which can be taken out of the optical axis by sliding it out of the retaining sleeve. In some microscopes it can be moved up and down in the axis by the aid of a screw control. Note also the diaphragm and its lever, which control the amount of light passing through the condenser.

Test each of these movements slowly and carefully.

USING THE MICROSCOPE

Having examined the microscope, identified its parts and tested their movements, the next stage is to use the microscope.

Many users never get the best out of their instruments because they fail to learn the principles involved.

These can be reduced to two statements:

(*i*) That the objective forms a *real image* which is projected up the tube.

(*ii*) That the eyepiece is used to magnify this image and examine it as a *virtual image*.

It is important to learn how to set up the microscope quickly and effectively. The following procedures are suitable.

A. With artificial illumination:

1. Set up the microscope without objective or eyepiece; incline the body to a convenient angle.
2. Place a microscope lamp between 6 and 8 inches away from the front of the microscope.
3. Using the plane mirror, reflect light into the tube so that it is centrally illuminated.
4. Place the low-power objective and the high-power eyepiece in place.
5. Focus the objective. Place a slide on the stage, holding it in position with the stage clips. By visual inspection, from the side, lower the objective until it is just above the cover glass surface. Next rack the optical system *upwards*, using the coarse adjustment very carefully and slowly. The image of the object will be found without risking damage to the objective or the slide.
6. Focus the condenser. First place it in the optical axis, as low down from the stage as possible, and then slowly move it upwards. While doing this hold a pencil point in front of and close to the lamp and view the field through the eyepiece. When the image of the pencil is clearly seen in sharp focus the condenser is focussed for use.
7. Control the light by removing the eyepiece and, while looking into the tube, close the condenser diaphragm until the cone of rays just fills the objective.
8. For critical focussing use the fine adjustment, controlled by the smaller milled wheel. This has a stop. When the stop is reached, reverse the direction. If critical definition is not yet obtained it may be necessary to adjust the coarse adjustment a little, by looking from the side.
9. When changing from the low-power objective to the high-power, by rotating the nose piece, be sure that there is sufficient clearance for the longer objective. After changing over it may be necessary to refocus the whole system by the method described.

Note: Even with artificial light it is a common mistake to use too great an intensity of illumination. One way of correcting this error has already been mentioned: visual examination of the inner tube, with eyepiece removed, and closing of the condenser diaphragm until the cone of rays from the condenser only just fills the objective field.

A second device is to use a diaphragm immediately in front of the lamp. The easiest way to effect this, at little cost, is to use a cardboard screen, with holes of different sizes, in front of the lamp. More convenient is the use of a rotating disc, or a sliding panel, with holes of different sizes.

B. With daylight illumination:

The use of direct sunlight should be avoided. Light reflected from the sky or, where position allows, light reflected from a nearby wall, is preferable.

The microscope is set up in the manner already described.

1. Set the instrument up, before an open window (avoiding obstruction by window bars).
2. Reflect light with the plane mirror into the tube and place objective and eyepiece in position.
3. Place a slide on the stage.
4. Focus the objective as described earlier.
5. Focus the condenser as described earlier.
6. Adjust the light intensity as described earlier.
7. Proceed as already suggested when objectives are changed.

SOME HINTS ON MAKING OBSERVATIONS

(*a*) Learn to use the microscope with both eyes open. This requires practice. In the early stages one eye may be covered by the hand, or even an eye shade, but the eye should remain open.

(*b*) Always use the least intensity of illumination which will permit observation. To exceed this not only causes visual fatigue, but may even obscure detail by 'flare', 'halo', etc.

(*c*) Learn to use appropriate filters for whatever work is in hand.

(*d*) Examine as many examples as possible of any one structure or specimen, if possible prepared in a variety of ways. This avoids the danger of accepting an abnormality as a normal structure.

(*e*) Always note the objective and eyepiece used, as a record of the magnification for a particular observation.

(*f*) Always note and record details relating to the specimen: name, origin, mode of preparation, etc.

(*g*) Make large clear drawings.

'DO'S' AND 'DONT'S' IN MICROSCOPY

DO

Proceed through the proper 'microscope drill' for setting up the instrument.

Focus by moving the objective away from the slide (i.e. upwards).

Use the controls carefully and slowly.

Keep the instrument protected by a cloth or plastic cover when it is left out during use.

Keep the instrument in its box when not in use.

Use a camel-hair brush and very soft tissues for cleaning eyepieces and objectives.

Use a cover glass on all specimens examined with high-power objectives.

DON'T

Take 'short cuts' in procedure; they seldom save time and often cause damage.

Focus by turning the objective downwards towards the slide; you may damage the objective and slide.

Force the instrument in any way; you may damage the mechanism.

Leave the microscope uncovered or unprotected; it may collect dust or be damaged.

Use harsh cloth for cleaning lenses; it may scratch the glass surfaces.

Use xylol to clean objectives or eyepiece; it may loosen their setting.

Use high-power objectives to examine wet specimens without a cover glass; it may cause damage to the objective.

II THE HAND LENS

INTRODUCTORY NOTE

The hand lens, which is small, cheap and easy to use, should be the constant companion of all students and teachers of biology, as it is the simplest aid to observation.

STRUCTURE

The simplest form of hand lens is a bi-convex lens. For protection and ease of use it is usually mounted in a frame with a handle. A convenient form is the folding pattern in which the lens folds inwards between protective covers which act as a handle. A hole in the handle allows the lens to be mounted on a pillar, etc.

The magnifying power is shown as ×2, ×5, ×10, etc., and is a function of focal length. Each lens has an effective numerical aperture which can only be exploited when the lens is correctly used.

To overcome problems of spherical and chromatic aberration various corrections are applied to the better lenses and the superior grades may consist of an assembly of two lenses.

Multiple folding lenses, in which one, two and three components can be used to achieve increasing degrees of magnification, are commonly available.

As magnification increases the field of view covered decreases.

USE

Keep the lens clean and dust free by using a purse or other protective cover.

Wipe dust off the surface with a soft cloth or lens tissue.

Avoid allowing liquids to come in contact with the lens.

To examine an object hold the lens as close as possible to the eye and bring the object into focus by moving it towards the lens. (If the lens is held away from the eye the field of view is greatly reduced.)

III NEW MICROSCOPE DESIGNS

A modern development in microscope design has been to bring about changes of focus by moving the stage rather than the microscope tube. An important point here is that if the rack and pinion become worn and loose, the stage falls away from the objective so that neither slide nor the objective is damaged.

The fixed vertical body, by keeping the stage flat, facilitates the use of wet specimens. The inclined tube however is less convenient for attaching a camera.

Modern design also includes improvements in binocular microscopes which often have a third tube for a camera attachment.

While these new ideas in design will only slowly affect the school situation, teachers should become aware of them and, when chance occurs, equip their laboratories with the new types of apparatus.

APPENDIX C

ELEMENTARY GUIDES TO HANDICRAFT WORK

The teacher who is able to use simple hand-tools and carry out elementary constructional, repair and maintenance work, is able to improve and extend the resources of his laboratory. The books named in the list which follows have been selected as most likely to provide guidance for those who have little or no previous experience.

ADAM, H. M., & EVAN, J. H. *Metal Work.* Arnold

BAGLEY, W. A. *The Boy's Book of Metal Craft.* Vawser & Wiles

BAGLEY, W. A. *Tin Can Craft.* Vawser & Wiles

BARKER, A. W., & CHAPMAN, C. *Workshop Practice for Schools and Laboratories.* Sidgwick & Jackson

BAYLEY, T., & TOMLINSON, R. R. *The Craft of Model Making.* Dryad Press

BLACKBURN, R. G., & CASSIDY, J. *Sheet Metal Work,* Parts I and II. Arnold

DUCKWORTH, E. H., & HARRIES, R. *The Laboratory Workshop.* Sidgwick & Jackson

ELLIS, P. E. *Introduction to Workshop Practice.* Blackie

EMERY, A. S. *Elementary Carpentry and Joinery.* Macmillan

GLENISTER, S. H. *Technical Drawing for Schools,* Bks. I, II, III. Harrap

HAWLEY, F. L. *Drawings and Diagrams for the Metal Work Class.* Murray

HAYWARD, C. H. *Carpentry for Beginners.* Evans Bros., London

IRVING, R. *Metalwork, Step by Step Books:* 1. *Bench Work* 2. *Sheet Metal Work* 3. *Beaten Metal Work* 4. *Forge Work and Lathe-work.* Warne, London

NOKES, M. C. *Modern Glass Working.* Heinemann

PARKE WINDER, W. E. *Simple Glass Blowing.* Crosby Lockwood

PARKINSON A. C. *A First Year Engineering Drawing.* Pitman

SAWYER, W. W., & SCRAWLEY, L. G. *Designing and Making.* Blackwell

TELLING, M. T. *Carpentry and Joinery.* Pitman

TURPIN, A. R. *Soldering and Brazing.* Percival Marshall, London

APPENDIX D

LIST OF HAND-TOOLS FOR A BIOLOGICAL LABORATORY

1 Hand-saw, small, approx. 18″ blade, for cutting boarding, planks, etc.
1 Tenon-saw, medium, for end cuts, joints, etc., 10″ blade
1 Hack-saw, adjustable frame for metal-work
1 dozen Hack-saw blades, medium, for previous item
1 Fret-saw frame, 12″ and 3 dozen medium blades
1 pair Tinman's snips, straight, for sheet metal, 2″ cut
3 Firmer-chisels, for work-work, 1″, $\frac{1}{2}$″ and $\frac{1}{4}$″
1 Mallet, wooden
1 Hammer, claw-head, for wood-work
1 Hammer, ball-head, for metal-work (1 lb. weight)
1 Try-square (for use with metal and wood), 6″
1 Marking-gauge for wood-work
1 Centre-punch for metal
1 Gimlet for wood-work
1 Marking-scribe for metal
2 Screwdrivers, 10″ and 6″ blade
1 pair Carpenter's pincers, 8″
1 pair Wireman's pliers, flat nose, 8″
1 Carpenter's brace
1 set Drill bits for carpenter's brace, 1″, $\frac{1}{2}$″, $\frac{1}{4}$″
1 Drill, breast or hand, for metal work
1 set Twist drills $\frac{1}{4}$″, $\frac{3}{16}$″, $\frac{1}{8}$″
1 Soldering iron, wedge nose, 8 oz. weight
4 bars Tinman's solder, soft
1 tin Flux, 4 oz.
1 Carpenter's rule, folding, 2 feet
1 Engineer's rule, steel, 12″
12 sheets Glass paper, assorted
12 sheets Emery cloth, assorted
1 Vice, carpenter's, 6″ jaws
1 Vice, metal-work, 3″ jaws
1 pair Dividers, spring, 8″
1 File, flat, medium cut, 10″
1 File, flat, fine cut, 8″
1 Smoothing plane, 2″ iron
1 Sharpening stone medium grade, 2″ wide

1 Blow lamp, paraffin, to heat soldering iron, ½ pint (this may be replaced by Primus stove or gas, if available)

Nails, screws, small aluminium rivets, washers, etc., various
Plywood, wood, sheet metal, various
1 small bench or stout table
Scrap of all kinds is often useful and should be collected.

While it is desirable to have all these available, much constructional work can be done with a few key tools. The complete set may be built up over a period of time.

APPENDIX E

PAPER BOUND BOOKS AND REPRINT SERIES

The various editions of paper bound books make available much valuable background teaching material to schools. By careful selection it is possible to build up an extensive library quite cheaply.

Such books are available in various languages, being published in many parts of the world. Among those in English the following series may be mentioned:

Series	Publisher	Address
Penguin and Pelican	Penguin Books Ltd.	Harmondsworth, Middlesex, U.K.
Ann Arbor Paper Backs	University of Michigan Press	Ann Arbor, Michigan, U.S.A.
Compass Books	The Viking Press	625 Madison Ave., New York 22, U.S.A.
Viking Portables	The Viking Press	625 Madison Ave., New York 22, U.S.A.
Mentor Books	New American Library	501 Madison Ave., New York 22, U.S.A.
Signet Books	New American Library	501 Madison Ave., New York 22, U.S.A.
Torch Books	Harper Bros.	New York, U.S.A.
Foundation Series	Prentice Hall	New York, U.S.A.

There are of course other series of paper backs, many of which contain materials from the field of science. Teachers, Librarians, Inspectors and others who wish to keep up-to-date should obtain publishers' catalogues. There is also available a quarterly journal, *Paper Bound Books* (U.S. $6.00 a year) published by R. R. Bowker Co., 62 West 45th St., New York 36, U.S.A.

A brief selection of paper backs dealing with various aspects of biology likely to be of interest at the top form level of Secondary Schools is given below:

I. From Penguin Books Ltd.

ABERCROMBIE, M., HICKMAN, C. J., & JOHNSON, M. L.	*A Dictionary of Biology*	5/–	
ABRAHAMS, A.	*The Human Machine*	3/6	A373
BARNETT, S. A.	*The Human Species*	5/–	A341
BRISTOWE, W. S.	*A Book of Spiders*	3/6	K35
BURNET, F. M.	*Viruses and Man*	2/6	A265
BUCHSBAUM, R.	*Animals without Backbones*	5/– each	A187, A188
FIELD, M., & DURDEN, J. V.	*See How They Grow*	3/6	A242

FISHER, J.	*Watching Birds*	2/6	A75
FOX, H. M.	*The Personality of Animals*	2/6	A78
GRAY, J.	*How Animals Move*	3/6	A454
HARRISON, R. J.	*Man, the Peculiar Animal*	5/–	A412
LAPAGE, G.	*Animals Parasitic in Man*	5/–	A394
MORLEY, D. W.	*The Ant World*	2/6	A240
NEWTON, H. W.	*The Face of the Sun*	3/6	A422
NICHOL, H.	*Microbes and Us*	2/6	A326
ROMER, A. S.	*Man and the Vertebrates*	5/– each	A304, A304
SMART, W. M.	*The Origin of the Earth*	3/6	A339
SMITH, K. M.	*Beyond the Microscope*	3/6	A119
SWINNERTON, H. H.	*The Earth Beneath Us*	3/6	A426
WALKER, K.	*Human Physiology*	3/6	A102
WALKER, K.	*The Physiology of Sex*	3/6	A71

II. From American Publishers

BUCHSBAUM, R. & M.	*Basic Ecology*	$2.35	Boxwood Press, Pittsburgh
CAIN, A. J.	*Animal Species and their Evolution*	$1.35	Harper (Torch Books) N.Y.
GAMOW, G.	*Biography of the Earth*	$1.35 and 50¢	Viking Press New Amer. Lib. N.Y.
GAMOW, C.	*Creation of the Universe*	50¢	New Amer. Lib. N.Y.
GAMOW, C.	*Birth and Death of the Sun*	50¢	New Amer. Lib. N.Y.
HANAVER, E. R.	*Biology made Simple*	$1.45	Doubleday, N.Y.
HANSON, E. D.	*Animal Diversity*	$1.50	Prentice Hall (Foundation Series) N.Y.
HUXLEY, J.	*Evolution in Action*	50¢	New Amer. Lib. N.Y.
RAPPORT, S., & WRIGHT, H.	*The Crust of the Earth*	50¢	New Amer. Lib. N.Y.

APPENDIX F

A SHORT LIST OF BOOKS ON THE TEACHING OF BIOLOGY AND RELATED TOPICS

This brief list does no more than indicate a few of the books likely to be found useful. In most cases they include other lists which will enable the teacher to build up a comprehensive bibliography and lay the foundation for a teacher's reference collection.

ANSLEY, A. J. *An Introduction to Laboratory Technique.* Macmillan
BATEMAN, G. C. *Fresh Water Aquaria.* Link House Publishers
BECK, C. *The Microscope.* R. J. Beck
BERKLEY, J. C. A. *Practical Plant Biology.* Univ. London Press
BIBBY, C. *Simple Experiments in Biology.* Heinemann
BOWLER, S. W. *Teach Yourself Photography.* English Universities Press
BRACHER, R. *Field Studies in Ecology.* Arrowsmith
BRACHER, R. *Ecology in Town and Classroom.* Arrowsmith
CROY, O. R. *Camera Close Up.* Focal Press
DAVIS, J. W. *Small Scale Qualitative Analysis for Schools.* Murray
EDEN, T. *Elements of Tropical Soil Science.* Macmillan
FOWELL, R. R. *Biology Staining Schedules.* H. K. Lewis
GRAY, P. *Handbook of Basic Micro-technique.* Constable
GREEN, T. L. *The Visual Approach to Teaching.* Oxford Univ. Press, Bombay
GREEN, T. L. *How to make and use Film Strips.* Pitman
GREEN, T. L. *Laboratory Work in Zoology* (Modern Sci. Memoirs No. 15). John Murray
GREEN, T. L. *Practical Animal Biology.* Allman
GREEN, T. L. *Zoological Technique.* Allman
GREEN, T. L. *Biology in the Secondary Modern School.* Allman
GREEN, T. L. *The Teaching and Learning of Biology.* Allman
GREEN, T. L. *Sub-miniature Camera Technique.* Focal Press
HODGE, A. E. *Vivarium and Aquarium Keeping.* Witherby
HOLDER, J. T. *Elementary Histology Techniques.* Churchill
JAYASURIYA, J. E. *Statistical Calculations for Teachers.* Macmillan
JOHNSON, J. C. *Microscopic Objects: how to mount them.* English Universities Press
KALMUS, H. *Simple Experiments with Insects.* Heinemann
LAMBER, J. *et al. The Essentials of Volumetric Analysis.* Heinemann.

LAYBOURN, K., & BAILEY, C. H. *Teaching Science to the Ordinary Pupil.* Univ. London Press

LLOYD, BLODWEN. *A Dictionary of Botanical Terms.* Univ. London Press

MCLEAN, R. C., & COOK, W. R. *Practical Field Ecology.* Allen & Unwin

MCLEAN, R. C., & COOK, W. R. *Plant Science Formulae.* Macmillan

MARTIN, L. C., & JOHNSON, B. N. *Practical Microscopy.* Blackie

MILLER, D. F., & BLADES, G. W. *Methods and Materials for Teaching Biological Science.* McGraw-Hill, New York

NUNN, G. *Handbook for Science Teachers in Secondary Modern Schools.* Murray

OLDROYD, H. *Collecting, Preserving and Studying Insects.* Hutchinson

PEACOCK, H. A. *Elementary Micro-Technique.* Arnold

Photographic Annual (B. J.). Greenwood, London

SCIENCE MASTERS' ASSOCIATION. *Secondary Modern Science Teaching.* Murray

SCIENCE MASTERS' ASSOCIATION. *The Modern Science Master's Handbook.* Murray

SCIENCE MASTERS' ASSOCIATION. *Science Books for a School Library.* Murray

SHOLTO DOUGLAS, J. *Hydroponics.* Oxford Univ. Press

SOWERBY, A. L. (ed.). *Dictionary of Photography.* Zeiffe

SUMNER, W. L. *Visual Education.* Blackwell

SUMNER, W. L. *Statistics in School.* Blackwell

TANSLEY, A. G., & EVANS, E. P. *Plant Ecology and the School.* Allen & Unwin

THOMPSON, H. S. *How to Collect and Dry Flowering Plants and Ferns.* Routledge

TWEDDLE, T. A. *The Science Teacher's Handbook.* Harrap

WELLS, A. L. *The Microscope Made Easy.* Warne

APPENDIX G

AN ANNOTATED LIST OF READING MATERIALS FOR PUPILS AND TEACHERS

Although there are book lists elsewhere, and although publishers' catalogues are usually available, teachers, especially young teachers, find it difficult to decide which books to choose. The difficulty is most pronounced where the choice has to be made from a catalogue, but may be present even when the actual books are available for inspection.

In order to help teachers to choose, further help in addition to the general comments made in Chapter VIII is offered in the annotations given below. These refer partly to textbooks, partly to general reading material and partly to specialist guides.

Space prevents selection of more than a few titles, but those chosen cover a wide range of subjects and exemplify certain principles already laid down. Thus, in earlier chapters, reference has been made to the value of overlay diagrams and stereogrammatic diagrams; there are references in this Appendix to books which display these features. There are also references to books which provide guidance on how to study special topics, such as the biology of a pond. The details will differ, but the principles involved do not. The teacher, with one or other of these books at his disposal, can adapt the general principles to his special circumstances.

A section of this appendix which will, it is hoped, be of special interest, is that part which refers to various kinds of special reports, reviews and articles which provide source material. From previous experience the writer knows that teachers in secondary schools in tropical countries have less easy access to research journals, specialist reports, courses of advanced study and the like than is the case with teachers in more highly developed societies. This particular section has been added to indicate to the teacher ways in which he can keep up to date despite the lack of certain amenities. In addition, it is introduced to indicate study topics and to suggest methods of study, because the author has always believed that pupils will gain understanding of science by learning how scientific knowledge is gained—and they will do this by trying to carry out experiments themselves. These various references indicate some of the topics, problems and methods which should be of interest.

In order to indicate how there can be a close connection between curriculum content and textbook design, and how both are affected by the general approach to biology, reference is made to the productions of the Biological Sciences Curriculum Study Committee.

Reference is also made to various other sources of materials which will be of value to teachers and their pupils.

Criteria for Preparation and Selection of Science Text Books. National Academy of Sciences, 2101 Constitution Avenue, N.W. Washington 25, D.C., U.S.A.

This very small pamphlet of some ten pages would repay the attention of all biology teachers. Although reference has been made to related topics earlier, this pamphlet is included here because it provides useful and practical advice.

The Committee responsible for the pamphlet has laid down four qualities which should be seen in all science texts:

1. They should distinguish clearly between fact and theory.
2. They should continuously emphasize the fact that any course is usually only a selection from the subject.
3. They should refer to unsolved problems in need of study.
4. They should show the relationships between the sciences and between science and society.

If every teacher were to make it his task to carry out those four things in his teaching, how much better education would be!

RENNER, G. T. *Conservation of National Resources*. Wiley, N.Y.

Reference has been made to the significance of biology teaching in connection with conservation. Teachers who do not find it easy to make the link between these two will find that this book, though written for use in the U.S.A., is particularly useful. It describes how to develop a conservation programme, describes underlying principles, defines objectives and discusses curricula and material sources.

WEAVER, R. L. *Handbook for Teaching Conservation and Resource Use*. National Association of Biology Teachers, Ann Arbor.

A very useful book on many aspects of conservation and natural resources. It contains many suggestions for activity, project and problem work.

BRANDWEIN, P. F., WATSON, F. G., & BLACKWOOD, P. E. *Teaching High School Science: A Book of Methods*. Harcourt, Brace & World Inc., N.Y.

Though dealing with science as a whole, this teachers' guide contains much of interest to the biologist. The treatment of theoretical aspects is of particular interest and focusses attention on the aims of science teaching and its evaluation. The various methods dealt with are not merely described, but critically discussed; indeed the evaluatory ideas are the most useful part of the book.

MORHOLT, E., BRANDWEIN, P. F., & JOSEPH, A. *Teaching High School Science: A Sourcebook for the Biological Sciences.* Harcourt, Brace & World, N.Y.

This possesses the same characteristics as the book referred to above, one author being common to both, but is devoted only to the biological sciences. Though the materials and methods could not be adopted directly, they are capable of modification to suit other conditions.

This should certainly be available to every biology teacher.

HELLER, R. (ed.). *Geology and Earth Sciences Sourcebook.* Holt, Rhinehart & Winston, N.Y.

Prepared under the auspices of the American Geological Institute, this excellent book contains much of value to the biology teacher and student. The sections devoted to stratigraphy and palaeontology would be of help in the study of evolution, and there are many useful ideas relating to teaching aids and demonstration methods. The bibliography, though geological, includes many references useful to biologists.

LUTZ, F. E. *et al. Culture Methods for Invertebrate Animals.* Dover, N.Y.

An old, but lately republished, book. It contains a wealth of information which can be used at school level provided that the teacher is willing to be inventive.

FLETCHER, G. L., & WOLFE, C. W. *Earth Science.* Harrap, London.

A fairly high level text arranged round a series of major topics, with enough detail to convey general principles properly. It would help to provide a background of understanding in relation to evolution, distribution, general ecology and the like.

WALD *et al. Twenty-Six Afternoons of Biology.* Adison—Wesley (U.S.A.), London.

Written for High Schools in the U.S.A. this book is mostly too advanced for the average secondary school in, for example, Singapore. However, it is noticed here because some of the work could be attempted, as it stands, some could be adapted and all is of interest. The book, though set out as a detailed guide, is at the same time a constant challenge to thought and ingenuity.

REID, D. *Elementary Ecology.* Allman, London.

Useful for its down-to-earth approach and sensible suggestions for simple field-work. These make the book valuable. Though it was written for use in England, it can be easily used by upper school pupils elsewhere.

KALMUS, H. *Simple Experiments with Insects.* Heinemann, London.

An extremely valuable review of general physiology and behaviour, with simple and precise directions for many experiments. Some, though not all, of these can be carried out in schools. An excellent example of scientific procedure.

HASKELL, G. *Practical Heredity with Drosophila.* Oliver & Boyd, Edinburgh.

After a simple description of techniques, the author shows how to conduct a number of genetic experiments. This field is usually dealt with as a theory because there has been such little help for the elementary worker. This book will prove of great value even if not all of it can be followed up.

GREEN, T. L. *Practical Animal Biology.* Allman & Son, London.

This practical guide to dissection is written on the principles referred to on pages 125–127 and 211 of this book. Attention is devoted to the procedures as well as the end result and a section on physiology in included.

ROWETT, H. G. Q. *The Rat as a Small Mammal.* John Murray, London.

This is introduced in this list, as an example of a detailed practical guide which is complete but simple, and as an example of what many teachers in tropical countries could well do for their own local type specimens.

TUKE, EVELYN. *Nature in Towns.* Educational Supply Association, London.

Many biology teachers whose schools are set in one or other of the great tropical cities, feel that the urban setting continually defeats them. This book will challenge them to effort and show that even the greatest city is a home of nature as well as of mankind. The genera and species may differ, but many of the problems and locations are the same. With this book at hand there will always be a challenge in every street, drain or waste plot.

It would prove especially helpful in devising studies in town ecology.

ELWELL, F. R. *Science and the Farmer.* Bell & Co., London.

Despite its setting and the fact that it deals with farm processes and products very different from those in the tropics, this book should help teachers to show the relationship between science (especially biological science) and farming.

Although the farmer in Asia may often enjoy high caste (as the *goigama* in Ceylon) he may be both poor and uneducated. He is thus in the grip of ignorance, superstition and tradition. Few farmers' sons want to go back to the soil and often little is done to give education to the farmer. This situation is dangerous in view of the world's population problem. One step towards helping the farmer to break through traditional barriers and adopt new methods, is to make more clear to all concerned the link between science and farming.

GRAMET, C., & MANDEL, J. *Biology Serving You.* Prentice Hall, N.Y.

This text is selected as an example of unit organization. Each unit, or group of units, is concerned with a single main principle in biology. There is a strong emphasis upon the social implications of biological knowledge. As is common to American texts, the approach is through the setting of problems, rather than through didactic statements. Illustrations are numerous and there is a good bibliography.

DALE, ALAN. *Observations and Experiments in Natural History.* Heinemann, London.

Although written for temperate conditions, the biological phenomena dealt with are common to the tropics. Thus, while many types and some phenomena are atypical, the basic observations and experiments can be transferred with little adaptation. The emphasis upon scientific thinking, the demands for accurate observation and the help given in planning experiments will all be found most useful. Care will be needed in the controlling of some of the experimental situations.

The work described ranges from that which is suitable for School Certificate forms, upwards.

GUILCHER, J. M. *The Hidden Life of Flowers.* Oliver & Boyd, Edinburgh.

This book consists of a series of photographs, on scales from ×2 to ×1050, of flowers and flower parts. Apart from its direct botanical content it provides exquisite evidence of the value of photography to the biology teacher. This is one of a series of books. They are all of a similar type, but each deals with a different aspect of nature.

CARSON, S. M. B., & COLTON, R. W. *The Teaching of Rural Studies.* Edward Arnold, London.

The world threat of starvation and the need to think and teach about conservation demand that biological education should have social application. The urban drift, so marked in many tropical countries, has to be overcome if rural productivity is to be stepped-up. One step towards helping in this situation is the improved teaching of rural studies.

This book, outspoken, idealist and practical, despite its setting, should provide help for every teacher who wants to give rural studies a greater value in education.

DE COURSEY. *The Human Organism.* McGraw-Hill, N Y.

An excellent well-illustrated general textbook of human anatomy and physiology. It is fairly advanced but clear and lucid and well illustrated. It would fill a real gap in the school biological library.

DE BEER, G. (ed.). *Evolution by Natural Selection.* Charles Darwin and Alfred Russell Wallace.

A selection of the more important writings of the two great architects of the theory of evolution. The best sixth formers could browse here with profit.

CARTHY, J. D. *Animal Navigation: How Animals Find Their Way About.* Allen & Unwin, London.

Another contribution to the study of animal behaviour, which should be encouraged in schools as being a biological aspect of biology, and one in which school nature societies could do good work. The factual descriptions in this book are useful, even if restricted to certain species and situations. The line drawings are good and the photographs excellent.

MACFADYEN, A. *Animal Ecology.* Pitman, London.

Condensed and in places difficult, but a comprehensive review likely to be of use as a reference text for sixth form teachers.

SANKEY, J. *A Guide to Field Biology.* Longmans, London.

A very practical book covering a wide range of problems, methods, apparatus and source references. An excellent book for all who really want to take biology out of the laboratory into the field.

A PI SUNER, translated by C. M. STERN. *Classics of Biology.* Pitman, London.

An historical review of the development of biological theory against the framework of philosophy and science. Valuable to teachers with good sixth forms.

THORPE, W. H. *Learning and Instinct in Animals.* Methuen, London.

A good academic review of a field often neglected but which has something to offer even at school level. This book should be a mine of ideas for the more advanced zoology classes.

COBLEY, L. S. *An Introduction to the Botany of Tropical Crops.* Longmans Green, London.

One of the few comprehensive books in English on its subject. Discusses the origin, history, distribution, taxonomy, structure and uses of tropical crop plants and should be valuable, especially for its illustrations, in many ways.

THOMAS, W. L. *Man's Role in Changing the Face of the Earth.* Chicago and Cambridge University Press.

This is a report of an international symposium and includes over fifty papers and many discussions. Though too expensive for a school library, teachers should know it because it has a special reference to the problems of conservation. It could well be available in a central reference library or a teachers' reference library.

BATES, M., and HUMPHREYS, P. S. *The Darwin Reader.* Macmillan, London.

Here is a convenient series of extracts from the voluminous works of Charles Darwin. It provides an opportunity for the sixth former to get into contact with Darwin direct, and not through a second or third intermediary.

SIMPSON, G., PITTENBRIGH, C. S., & TIFFANY, L. W. *Life: an introduction to Biology.* Routledge, London.

An excellent book able to arouse interest and challenge response. Deals with a wide range of general principles. Well illustrated with clear drawings and good photographs.

SNOW, D. W. *A Study of Blackbirds.* Allen & Unwin, London.

An academic review of all aspects of the problems of bird life, illustrated by the study of a single species in a restricted habitat. It indicates what can be done by precise observation, careful recording and acute analysis.

OBOURN, E. S., HEISS, E., MONTGOMERY, G. C., & LAPE, R. H. *Discovering the World of Science,* Van Nostrand Co., N.Y.

Exploring the World of Science, Van Nostrand Co., N.Y.

Lavishly illustrated with photographs, many kinds of diagrams, graphs, tables, stereograms and overlay pictures, these books well repay attention, even though they are not confined to biology.

Indeed, that may well be one of their chief values, because they show biology as part of science as a whole and science in its relation to society.

The teaching approach is based on the belief that the teacher must deal with both the content (results) and methods (processes) of science, instead of presenting only a picture of the end-results of science. 'By understanding the processes of scientific enquiry, the student will be encouraged to seek out information on his own and to discover relationships in the world around him.' With this in mind, the subject matter is presented as a series of problems, these are explored through experience and experiment and the evidence obtained is analysed, hypotheses developed and concepts formed. These are suggestions for further reading and independent investigations. A Teachers' Guide is available for each book. The series will ultimately include other titles.

Very different from the British or Continental tradition, these books reflect the newer American attitudes on science teaching. The critical teacher will use the books with caution, backing them up with that solid grounding in details and skills which is demanded in a more traditional setting, but also gaining from the stimulating and thought-provoking attitudes of these texts.

Modern Science Memoirs. John Murray, 50 Albemarle Street, London, W.1.

No.	*Author*	*Title and comment*
9	O. H. Latter	*The House Fly*. A classic which should be available to every sixth former.
25	C. M. Yonge	*Crayfish and Lobsters*. Informative and clearly written by a master hand at exposition.
26	M. G. Jones	*The Bean and Beet Aphis*. Would help to focus attention on the applied aspect of biology.
27	G. Ingram R. Belcher B. L. Wilson	*Microchemistry*. Several methods could be used in biological work.
35	D. J. B. White	*The Study of Plant Anatomy*. Many useful suggestions for making the subject interesting.
37	G. Lapage	*The Potato Root Eelworm*. Stresses the applied aspect of zoology and the inter-relations of plants and animals.
40		*Modern Cytological Techniques*. Some simple enough for a well-equipped school to try out.

Science Teaching Techniques. John Murray, London.

This is a series of small booklets of 50–60 pages produced by the co-operation of four teachers' organizations. There is some tendency for the general level to be that of the lower and middle school, rather than that of the upper secondary school. The contents of each booklet are varied and not all are confined to biological science, though one or two are (e.g. No. IV). It would thus be desirable to obtain the complete series.

Indications of potential use may be seen in the following list of some of the biological topics:

Fish keeping in schools (I)
A classroom aquarium (I)
Keeping small mammals in the laboratory (I)
Experimental physiology in schools (I)
The teaching of evolution (II)
The use of small mammals in the school science course (II)
The use of museums (III)
Classroom experiments with soil (III)
Suggestions for field work (III)
Feeding frogs in captivity (III)
Bird watching in secondary modern schools (IV)
Seashore studies for the secondary modern school (IV)
Suggested practical work for a topic on microbes (IV)
Keeping newts in captivity (IV)
Some notes on leaves and stomata (IV)
The school greenhouse (V)
Watercress as an aid to biology (VI)
The use of photography in science teaching (V and VI)
Genetics on the farm (VI)

Later issues have extended the number of biological articles included in the series. This whole set would be valuable for science teaching as a whole.

WILSON, J. *Thinking with Concepts*. Cambridge University Press.

It is of little use demanding that our pupils and students 'think for themselves' unless we give them help, guidance, even instruction in the art and techniques of thinking. This is no easy task and one where the teacher himself will need help.

One form of help he will need is a book which can be used with his sixth formers as a text, for discussion, as a source of examples and so on. This particular book will be most useful although little of it is directly connected with the scientific world.

INHELDER, B., & PIAGET, J. *The Growth of Logical Thinking*. Kegan Paul, London.

Related to the note above, reference may also be made to this outstanding book of fundamental importance. Though it is concerned with young children, it forces attention on problems which confront every teacher at every stage of education. The higher the level the harder the problem, and the greater the difficulty of understanding. Here is a book which will help the teacher to understand why the pupil cannot understand. It will therefore contribute to the designing of better teaching methods.

Museum publications

Most museums, and botanical gardens, publish reports and brochures, many of which make excellent background teaching materials especially in regard to their illustrative value. Some will be of much too high a standard, so careful selection is necessary. As an example of a few such products from a single source the following may be noted:

British Museum (Natural History), South Kensington, London, S.W.7.

W. E. LE GROS CLARK. *History of the Primates*. Clear and brief, with good illustrations, this 100-page booklet tells a fascinating story which would capture the interest of any good sixth former. It ties palaeontology to geological succession, explores systematic relationships and those between biology and climate.

K. P. OAKLEY. *Man the Tool Maker*. Specialized but well illustrated and carries further the subject surveyed broadly in the *History of the Primates*. Has usually aroused a good deal of interest among sixth formers.

Various Authors. *British Caenozoic Fossils*. Localized and specialized but beautifully illustrated. For the many areas which are unfossiliferous, but with pupils who have to learn about evolution, this would prove very useful.

SONIA COLE. *The Neolithic Revolution*. This would have a wide appeal because it takes a world (or middle old world) setting and deals with materials and methods not unknown to modern pupils in underdeveloped areas. Could be tied in with the study of the relations between science and human progress.

K. P. OAKLEY & H. M. MUIR-WOOD. *The Succession of Life through Geological Time*. An absolute 'must' for every pupil trying to understand evolution. Clear, concise but with an enormous coverage and excellent illustrations.

The British Museum (Natural History) publishes many other booklets and teachers should seek the aid of the local British Council representative in getting information about them. The standards are high and the prices low. Their chief value is as 'background reading' and the way in which a scholarly presentation, devoid of all attempts at sensationalism, nevertheless grips the interest.

From the museums of Europe and the Americas and from some in Asia similar materials are available. There may be a language barrier —but pictures speak a universal language. Special attention should therefore be given to the *post card series* which so many museums publish.

Biological Sciences Curriculum Study Committee, University of Colorado, Boulder, Colorado, U.S.A.

B.S.C.S. High Biology Series

Supported by funds from the National Science Foundation, the American Institute of Biological Sciences set up a Biological Sciences Curriculum Study Committee. This Committee, working on a very extensive scale of collaboration, has been responsible for what is claimed to be a revolution in high school biology teaching.

Biology teachers in many parts of the world have been interested in this work and, in some places, the B.S.C.S. materials are being adapted for local use. Any teacher who is interested should write to Dr Arnold Grobman, at the address given above, for full information. The notes which follow, in the form of brief annotations, will indicate something of the scope of the work.

General Aims. Having surveyed the field of American biological education the Committee brought together a team of biologists and teachers whose primary purpose was 'to prepare first high school biology courses, suitable for wide use in the average high school, with average classes, to give students a basic understanding of science and of scientific processes, and in so doing, to build scientific literacy in order to aid in the preparation of the student for later responsible citizenship'.

To fulfill these aims the Committee has produced three separate versions of its curriculum text and a number of supporting publications. Running through all the versions there are nine basic unifying emphases presented as:

change of living things through time—evolution
diversity of the type and unity of pattern of living things
genetic continuity of life
biological roots of behaviour
inter-dependence of organisms and environment
regulation and homeostasis: the maintenance of life in the face of change
science as enquiry
intellectual history of biological concepts

Reference to Chapters 2 and 4 in this book and to similar chapters in earlier works of the present author, will show that the B.S.C.S. presentation is a variant on a theme, long accepted, to the effect that biological education must present the main principles of the subject. The B.S.C.S. Committee, however, feels that their presentation bears three important characteristics:

a. It is a high school programme which stems from genuine co-operation between 'significant teams of research biologists, high school biology teachers'.
b. It represents 'not a revision of old thinking . . . but rather a completely new start, based on the most up-to-date thinking in the field of biology'.
c. It puts a greater stress on laboratory work than do traditional texts. (This is a reference to the American situation. See p. 93 in this book which shows that in a two year sixth form biology course in an English public school covering 650 class periods, 428 were for practical laboratory work and 222 for class theory. In addition there would be, especially in a boarding school, a great deal of both individual and group field-work outside the time-table.)

The B.S.C.S. materials have been prepared in three editions known as the Blue, Yellow and Green versions. Each takes a different approach though all cover the same biological ideas. The versions differ significantly, the green version emphasizes the community angle, while the blue version centres on a molecular approach and the yellow on the cellular approach.

In addition to the basic texts, each in three versions, there are associated materials, such as laboratory guides, guides to field-work, and guides to special investigations and special topics.

The whole series appears to be in a state of flux, undergoing trial and revision and being rapidly extended.

The following notes will indicate something of what is available and the ways in which teachers in tropical countries may find it useful.

Laboratory and Field Studies in Biology. A Source Book for Secondary Schools.

a. Students' Edition
b. Teachers' Edition

These two books, closely tied in with the general ideas of the B.S.C.S. textbooks, provide a wide background knowledge considered essential to the proper understanding of biological ideas. The two versions are of course written from different standpoints, but both would be very useful in any biological class or course.

They have a common plan, being each divided into 7 sections:

1. Organisms in their particular environment
2. The diversity of organisms
3. Some essential chemistry
4. The organism as a dynamic system
5. Maintenance of the individual
6. Maintenance of the species
7. The organism in its ecological setting.

Biological Investigations for Secondary School Science Students

Part One. (One hundred projects)
Part Two. (Fifty-one projects)

These two very interesting volumes obviously found their place because the B.S.C.S. stresses the place of gaining not only knowledge, but an understanding of how that knowledge was gained by scientists. As such an understanding is more likely to be obtained, retained and applied when based on experience, than if obtained only from 'taught' work, the provision of a guide whereby the student could undertake his own elementary investigations is an obvious step.

These guides, covering a wide range of topics, are likely to be thought too ambitious by many teachers in tropical secondary schools, where the physical resources are not likely to be available and where the necessary 'questing' outlook has yet to be developed. However, they should certainly stimulate the teacher who could select and adapt topics, treating them in less complex ways. Some of the many topics included are:

Influence of light and temperature on the activity of fishes
Influence of light and temperature on the seasonal distribution of micro-crustacea
A comparative study of the pectoral girdle in the Hylidae
A study of the fauna in the soil
Variations in the mouth parts of tadpoles
Effect of tranquillizers on learning (in rats)
Seasonal aspects of a selected community
Effect of chemicals on regeneration rate of Hydra
The use of proteins in determining evolutionary relationships.

The Teachers' Handbook. Parts I, II and III.

The three-volume teachers' handbook relates to all three editions of the B.S.C.S. Course. Part I deals with an examination of the aims of the Course. Part II is concerned with a discussion of attitudes to science teaching and the presentation of an argument in favour of the 'enquiry' approach. Part III is devoted to scientific method. All are of interest but some of the ideas have been already put forward earlier by other writers.

B.S.C.S. 'Specials'

In effect these are small fairly simple monographs on biological topics. Their value lies in making easily available to the teacher materials which are scattered widely, or which are available only at advanced level. The titles available include:

Microbes: their growth, nutrition and incubation
Interdependence of structure and function
Animal behaviour
Regulation in plants by hormones
Plant growth and development
Animal growth and development
The ecology of land plants and animals.

The Laboratory

For each version B.S.C.S. has provided what are usually known as Laboratory Guides. In the B.S.C.S. series these books are simply called 'The Laboratory'. Thus there are Green, Yellow and Blue versions and for each The Laboratory includes a Teachers' Edition and a Students' Edition. The latter is in three parts.

Though geared to a specific text these books all contain material and ideas of interest to teachers. They are particularly useful in terms of their practical approach.

The use of Source Materials in teaching biology

Reference has been made earlier in this book to the desirability of getting pupils interested in making their own investigations. In order that they may do this they need the resources not only of the laboratory, but of the library. While this will contain books and magazines it could also well provide opportunity to see up-to-date reviews on special topics.

Personal experience in teaching by the present writer has made it clear that pupils benefit from contact with 'the real world of Science'. It has, however, also made clear the difficulty of achieving it in many settings in Asia. Here the grip of tradition and many other factors tend to confine attention to the syllabus. One of these factors is the difficulty of getting access to suitable materials. In order to help overcome this particular difficulty there are names of sources and lists of typical written materials likely to be of value.

Potential users of these materials should be clear about why and how they should be used. The reasons for using them can be reduced to a single statement—*to stimulate interest.* Interest, the greatest incentive to effort, will open new vistas, show new relationships and so widen and deepen understanding. As to how to use them—one thing should at once be clear—these are not to be offered as extra set work, to be learned and tested! They are to be made available freely, informally and at any time. They are to be browsed in, looked over and come back to, time after time; discussed, used as models and, in general, seen for what they are—a distant flash of the exciting world of real science.

Scientific American Reprints

Written for adults and at a fairly high level these reprints could however provide stimulating material for a good sixth form. They are obtainable through any bookseller from W. H. Freeman and Company, 660 Market St., San Francisco 4, California, U.S.A., at a sterling price of 1*s.* 6*d.* each in most cases.

No.	*Author*	*Title and comments*
27	D. Mazia	*Cell Division.* A good description with clear diagrams and excellent photo-micrographs which will prove very helpful.
93	D. Mazia	*How Cells Divide.* A more complete treatment with valuable pictures.
45	C. H. Waddington	*How do Cells Differentiate?* Apart from telling what we know about the control of differentiation, this review shows how the procedures of study in this field have changed. The early and exciting micro-surgical techniques, which led us to 'organizers', have led on to chemical ideas derived from new and more subtle techniques.
91	A. L. Lehninger	*How Cells transform Energy.*
94	M. Fischberg & A. W. Blackler	*How Cells Specialize.*
95	A. A. Moscona	*How Cells Associate.*
96	H. Holter	*How Things get into Cells.*
97	T. Hayashi	*How Cells Move.*
98	B. Katz	*How Cells Communicate.*
99	W. H. Miller, F. Ratcliff, & H. K. Hartline	*How Cells receive Stimuli.* Reprints 91–99 named above are a little difficult but are very well illustrated. They deal with phenomena which we expect sixth formers to understand, though we seldom provide the data whereby the understanding might be achieved. Few school pupils will get more than a little real understanding from these papers, but all will get excitement and interest as well as some idea as to how knowledge is gained.
39	T. M. Sonneborn	*Partner of the Genes.* A well-illustrated account of the experiments which show that the whole cell, not merely the nuclear structures, is involved in the determining of heredity.

No.	*Author*	*Title and comments*
48	G. Wald	*Innovation in Biology*. A brief survey of the way in which certain basic biological ideas have arisen, been rejected and come back in new forms.
47	G. Wald	*The Origin of Life*. A little difficult, but a good student should get a thrill from its breadth of vision.
832	R. Broom	*The Ape Men*. As exciting as a thriller, a fine picture of how scientific knowledge is built up, and of the difficulties involved in the process.
806	E. H. Colbert	*The Ancestors of Mammals*. Brief résumé of one of the great steps in evolution, the change from reptile to mammal.
831	J. Millot	*The Coelocanth*. The 'living fossil' story, its implications for evolutionary theory and its suggestion and challenge for further research and discovery.
834	E. S. Deevey	*Living Records of the Ice Age*. Apart from its analysis of biological data this provides valuable evidence on the technique of thinking and problem solving.
601	S. L. Washburn	*Tools and Human Evolution*. 'Give us the tools . . .' and we who were pre-human became human! The story of man as the maker of tools—and so of civilization.
6	T. Dobzhansky	*The Genetic Basis of Evolution*. The schoolboy's struggle with elementary genetics often hides the fact that he is dealing with the mechanical basis of evolution. This very clear exposition will provide a new perspective for understanding.
846	L. C. Eiseley	*Charles Lyell*. Interesting review of the work of a pioneer whose *Principles of Geology* influenced Darwin's thinking though Lyell himself was a reluctant evolutionist.
842	H. B. D. Kettlewell	*Darwin's Missing Evidence*. Darwin perfected a theory which, however logical, had no mechanistic explanation and no demonstration of evolution in action. In his own lifetime, however, both were provided. The first by Gregor Mendel, the second in the series of colour changes, induced as a response to industrialization, in the moth *Biston betularia*. This paper gives an interesting survey which any sixth former can follow and understand.
17	N. H. Horowitz	*The Gene*. Quite apart from its science content this paper is an interesting record of the history of Science. The author shows how de Vries in Holland, Correns in Germany and Tschermak in Austria had all independently developed what each thought to be a new theory of inheritance. Then they came across the work of Gregor Mendel whose first report was written in 1866. It lay hidden and unrecognized in many university libraries in Europe until 1900—when it was found to have forestalled the work just then being done! The review which Horowitz has written would itself, because of the work of Crick and others, take a new form if re-written now.
49	C. M. Williams	*The Metamorphosis of Insects*. Well written and well illustrated, this review of a phenomenon which

No.	*Author*	*Title and comments*
		anyone can study shows how subtle reasoning added to simple techniques can lead to new scientific ideas.
63	V. B. Wigglesworth	*Metamorphosis and Differentiation.* A brilliantly simple description of epoch-making ideas in insect physiology—by the man who made the discoveries on which they were based. Also an excellent example of the development of scientific thinking which grows from humble beginnings, step by step, towards a final hypothesis—which may be upset by a new discovery or by a new evaluation of an old idea.
79	P. Satir	*Cilia.* In 1950 we thought we knew all about cilia, secure in knowledge which had been built up from 1676 when van Leeuwenhoek first saw them. The electron microscope has, in the past ten years, opened up a new world of ciliary knowledge. Now the story, well told and illustrated, is in the forefront of the relations between structure and function—and techniques and knowledge.
73	W. G. Walter	*The Electrical Activity of the Brain.* Of value because it shows the relation between technique and knowledge and illustrates again how a new idea can often lie unaccepted because its value is at first not recognized—as was the case of Berger's 'brain-wave'.
34	E. I. Rabinowitch	*Photosynthesis.* An excellent example of what an academic writer can do to present his material in a way which is challenging and informative. Starting with an historical statement the story of photosynthesis is traced up to some of the middle work on Chlorella. The inter-dependence of biology and other kinds of knowledge, as well as of technical advance and increases of knowledge are made very clear. Any student who reads this and sees the excellent diagrams would have a richer understanding of the cycles of carbon, hydrogen and oxygen than is commonly available in school texts.
107	W. L. Butler & R. J. Downs	*Light and Plant Development.* Provides a good background for understanding something usually included in the school syllabus . . . but usually known in a sketchy way. Could be used as a basis for some simple school experiments.
12	V. Grant	*The Fertilization of Flowers.* Readable and well-illustrated account of certain relationships between plants and animals (mostly insects) which have evolutionary significance. Also demonstrates the value of field-work and of the naturalist's approach.
113	A. W. Naylor	*The Control of Flowering.* Brings together geographical and biological data and indicates the application to agriculture of a knowledge of plant habits based on experimental control. Could provide several ideas for school studies, especially if read in conjunction with paper No. 112.
112	F. R. Salisbury	*The Flowering Process.* Extension of No. 113 published six years earlier. Indicates some simple techniques which might be applied in school—some of which are referred to earlier in this book.

No.	*Author*	*Title and comments*
53	S. & O. Biddulph	*The Circulatory System of Plants.* A very well illustrated account of a process studied in school and usually dismissed after a few (or even one!) inconclusive experiments. Nicely relates structure and function and clearly describes the dependence of hypothesis on experiment.
116	W. P. Jacobs	*What makes leaves fall?* Many school texts still repeat the classical but misleading abscission layer story. This report is of particular value as it contains a concise résumé of the methods of experiment and of argument and indicates how misleading observations can appear to be. Many experiments could be devised after reading this.
117	D. Koller	*Germination.* Those who struggle to learn about the various types of seeds and fruits and about their dispersal usually also make a few experiments on germinating a bean . . . the former often seems too dull and the latter over-simple. This paper would soon show that the subject is fascinating and complex. It would stimulate interest and give a background to a great deal of work.
90	J. Brachet	*The Living Cell.* With its clear diagrams and up-to-date electron micro-photographs this would prove a valuable help to many a student who finds the normal textbook figure insufficient.
21	A. Krogh	*The Language of Bees.* A clear and simple description of the classic work by Von Frisch. Some of it is so simple in technique that schools could repeat or adapt it.
130	K. V. Frisch	*Dialects in the Language of the Bees.* Here the master tells his own story, which should fire the imagination of many a student.
413	T. C. Schneirla & G. Piel	*The Army Ant.* This well-written analysis of behaviour should be of especial interest as ants abound in the tropics. The observations recorded were made without elaborate apparatus or procedures. A School Natural History Club might well use this paper as a guide for its activities.
124	E. Shaw	*The Schooling of Fishes.* Describes an important phenomenon. Some of the methods used could be followed in a school aquarium.
424	C. J. Warden	*Animal Intelligence.* Interesting discussion of the main facts which should help to gain interest in the living and behaving animal.
412	K. Z. Lorenz	*The Evolution of Behaviour.* Full of simple wisdom and a tribute to co-operation in observational studies with minimal apparatus. Should lead the Natural History Society into field-work.

Publications of the School Nature Study Union

This old-established English organization was founded in 1903 with a motto which clearly defined its purpose—'To see and admire; not harm or destroy'. While the activities of the Union are unavoidably local its publications can be obtained by anyone in the world by sending the appropriate International Money Order to Mr A. C.

Funnell, 23 Crystal Palace Road, London, S.E.22, England, in the case of pamphlets, or to George Philip and Son Ltd, 32 Fleet St., London, E.C.4, in the case of the Journal.

Recent developments have led to a change of name for the Society and its Journal. The new names are The School Natural Science Society and *Natural Science in Schools*. The fundamental aims, even though widened, are basically unchanged.

The Society and its Journal are dedicated to the Study of Natural History and Natural Science, at school level and by simple means. There is no attempt at over-complication either in theory or practice. All that is dealt with is simple, direct and practical and can be put to use at once in school with a minimum of equipment. Practically every article in the Journal is based on school experience and can be used as a basis of school work, in class or field. Fortunately many of the articles are available as leaflets. In order to indicate what is available annotations dealing with a selection of titles are given below.

The Journal

The new version *Natural Science in Schools* appeared first in March 1963 (Vol. 1, No. 1). Free to members of the Society—it is priced at 4*s*. 6*d*. sterling plus postage to non-members. The annual subscription to the Society is 10*s*. sterling and the Subscription Secretary is Dr W. Page, 5 Dartmouth Chambers, Theobald's Road, London, W.C.1, England.

Apart from its own articles the Journal carries a large and very useful section devoted to reviews of books, visual materials, supplies, etc.

Back copies of previous issues are not easily obtained but copies of single articles from the past, if not in the regular leaflet series, can be obtained in photo-copy or other form.

The Leaflets

These leaflets have been in use as 'source material' in many schools in England for a very long time and have long demonstrated the value of self-enquiry, individual investigation and 'contact with the real scientists'. They have three important characteristics:

(i) They are simple and direct in approach and terminology.
(ii) They rely first upon observation and then on experiment.
(iii) They are essentially practical.

These characteristics make them excellent material to use in a first attempt to break away from the usual rather formal approach and to replace it with the more progressive methods of teaching and learning. Any of these pamphlets can be read and understood by a pupil or student who is able to read a biology text in English. They would provide a good introduction to the more complex reprints from the *Scientific American*.

Needless to say many of the topics or methods are restricted to a particular environment or geographical location—but the ideas and methods can be adapted to new conditions. This is rendered more easy by the fact that they were written by teachers for use by teachers, students and pupils.

The following examples indicate the kind of thing available:

No.	*Author*	*Title and comments*
4	C. von Wyss	*Seeds and Seedlings*. Simple experiments a young pupil can perform, yet leading to important observations. Some of the practical work might well be coupled with a reading of Darwin's classic work.
5	E. M. Tuke	*A Trout Hatchery in School*. Concise and simple directions with suggestions for observation and experiment. Might be modified for use with other species and so allow pupils to engage in really new work. Raises problems in general biology.
19 42 30	J. Groves	*Grasses* (in three parts). The grasses, one of the (if not *the*) most significant plant groups, gets scant attention at school level. Here are three pamphlets which provide an excellent general statement and a survey of selected species found in England. This should not prevent use of the pamphlet elsewhere as a first guide. Grasses make an excellent subject for those interested in collecting and they also provide an introduction to economic ideas in botany.
68	R. N. Chrystal	*Some insect wood borers*. An excellent survey which should prompt similar studies in tropical areas. Apart from general and economic interest this work can be linked up with collecting, the study of wood (in handicrafts) and with the activities of the school photographic society.
81	R. Rivers	*Biscuit Tin Aquaria*. Though the common large cubical biscuit tin is less easily obtained as junk in most tropical countries it can be found sometimes. This pamphlet shows how it may be used as the basic frame for constructional work. Better still, it provides ideas which can be adapted to other more readily available materials.

(The titles above refer to leaflets available at 6*d*. each plus overseas postage. The titles which follow are priced at 1*s*. 6*d*. each, plus overseas postage. The first series cost 5*s*. 6*d*. and the second 15*s*. a dozen if at least a dozen is ordered.)

2	J. Caiger Smith	*Bird Flight*. An excellent account of the relations between structure and function and on flight phenomena in general should stimulate the Natural History Society and suggest a number of study topics.
4	E. C. Pugh	*Deciduous Trees*. Despite the lack of such sharp seasonal variation as obtains in the tropics the leaf fall has peak periods and provides some interesting problems. Some of these need no more than careful and continuous observation coupled up with critical

No.	*Author*	*Title and comments*
		thinking about the data collected. Here is another chance for the Natural History Society. This work undertaken should be considered also in relation to the leaflet No. 116 of the *American Scientist* series.
6	R. F. Shove & D. A. Coult	*Seed Structure and Germination.* This should be used as a follow-up to No. 4 as it carries the whole study further and at a higher level. It describes possible experiments and suggests topics for observational study. Especially it is useful for its general observations of a process which, in the end, controls plant numbers and distribution. Should be read in conjunction with No. 117 in the *American Scientist* series.
8	J. E. Marson	*Water Animal Identification Sheets.* Though of little direct value in most tropical settings this leaflet shows a method whereby young pupils can be introduced to the elementary ideas of taxonomy.

(The following titles refer to leaflets which cost 1*s.* each or 11*s.* per dozen, plus overseas postage.)

No.	*Author*	*Title and comments*
9	D. Dixon	*The School Aquarium.* Methods which can be adapted to tropical conditions. Should lead to more activity in this line . . . far too few schools keep aquaria. Without them, and without attention to the garden and vivarium, biology becomes very unbiological.
11	V. B. A. Gregory	*The Keeping of Animals and Plants in School.* Provides simple instructions on many points and has a number of stimulating ideas.
13	J. E. Marson	*Indentification Sheets: Insects and other Land Arthropods.* Provides a simple introduction to taxonomy.
15	E. M. Stephenson	*Sea Shore Life.* Good straightforward survey relating systematics to distribution. Could be used as basis for similar observations on the local coast.
16	E. M. Tuke	*Earthworms.* Provides a model for observation and simple experiment and should be read in conjunction with Darwin's book.
17	B. E. Mackie, F. M. Green & J. Vinniconnbe	*Experiments with Leaves. How to make Prints and Plaster Casts of Plant Material.* Clear instructions for simple experiments and activities with descriptions of how the ideas are 'got over' to children.
18	J. M. Branson	*Study of the Soil.* An excellent description in detail of how to carry out a study of local soils, using simple methods and materials. Raises many problems and indicates many relationships which are often overlooked. Could be used as a guide, with modification, for work in tropical areas and should lead to a better understanding of soil and its effect on tropical plant growth.
19	F. W. Jane	*Natural History of a Piece of Wood.* At a time when a totally unnecessary series of complications is taken as a sign of progress this simple direct and thoughtful leaflet should be welcome because it is redolent of the classical manner of presentation. Much of it may be irrelevant in tropical conditions, but all of it should stimulate interest and challenge thought.
20	M. M. Hutchinson	*The Migration of Birds.* Will help to make biology more biological. Should stimulate local studies and draw attention to many local problems of bird behaviour.

U.S. Department of Health, Education and Welfare, Washington, D.C., 25, U.S.A.

This U.S. Office publishes a large number of pamphlets of potential interest to biology teachers and science teachers in general. Reference is made to a small number of these below. Full details would be forthcoming on application to the nearest branch of the U.S. Information Service.

Aids for Teaching Science is the title of a series of brochures prepared as one of the Selected Science Services. Attention is drawn to the following:

Professional books and magazines for the science teacher

This is an annotated list which provides, up to its date, a guide to materials primarily of American origin.

A suggested check list for a Science Programme

This would be useful in connection with the comments made in the present book on evaluation in Chapter 5. The check list is divided into sections with a very wide coverage—content, method, priorities, finance, staff and so on. Many teachers might feel inclined to say—'but we know all this'. That is often one of the reasons why the quality of teaching remains static . . . taking things for granted, becoming so used to shortcomings that they are forgotten. A check list of this kind forces attention on the familiar and so brings a re-appraisal.

Science as a Way of Life

Includes reference to material which would be of value in helping pupils understand the position of the scientist in society and the significance of science to society.

Books and Magazines for the Science Library

An excellent list of titles, mainly of U.S. origin.

Observation, the basis of effective Science Learning

An acute commentary which should help teachers to a better understanding of observation and its relation to learning.

Journals for the Biology Teacher

The American Biology Teacher, published by the (American) National Association of Biology Teachers (Editor, Department of Biological Sciences, Purdue University, West Lafayette, Indiana, U.S.A.), U.S. 4.50$ per year. Despite the fact that it is concerned with the American scene, this is full of ideas which can be modified for application elsewhere.

The Science Teacher, published by the National Science Teachers' Association. Editorial offices, 1201 Sixteenth St., W., Washington 6, D.C., U.S. 6$ per year.

The School Science Review. The Journal of the Science Masters' Association (Assoc. for Science Education). Although it ranges over a wide field of Science, there is always material related to biology present in it. Published by John Murray, 50 Albemarle St., London, W.1, 12*s*. 6*d*. plus overseas postage of 1*s*. 2*d*.

Natural Science in Schools. See earlier in this Appendix (under Source Materials).

Journal of the Institute of Biology (see later in this Appendix).

In addition to these, there are many other journals which may be of interest and use to the teacher. These fall into three groups:

(*a*) Commercially published natural history magazines which are now numerous and of high standard. Information can be obtained from publishers, representatives and the trade.

(*b*) Official publications, such as museum guides and reports, brochures and pamphlets from government departments, such as forestry, fisheries, agriculture, etc. Information can be obtained by writing to the Government Information Service or direct to the department concerned.

(*c*) Private publications, such as the reports and journals of the local natural history society. Every teacher of biology should find out about such local societies and support their activities, and obtain their publications.

International Union for Conservation of Nature and Natural Products. 31 rue Vautier, Brussels, Belgium.

The title indicates the interests of the Union and application to the Secretary will provide information of its activities and publications. These include two books of special interest to biology teachers:

Protect to-morrow's world to-day.
A guide to Conservation.

The Council for Nature. 41 Queen's Gate, London, S.W.7, England.

A co-ordinating body concerned with many aspects of nature. Publishes reports and supports activities. Teachers may get good ideas from contact with the Council.

Journal of the Institute of Biology

This Journal is published from Tavistock House South, Tavistock Square, London, W.C.1.

The Institute of Biology, with its offices and rooms at 41 Queen's Gate, London, S.W.7, is a professional and academic organization of biologists. The breadth of interests is well shown in the Journal, which carries reviews, reports, news and discussion and correspondence. Apart from the content of its Journal, likely to be of special interest to biology teachers at sixth form level, there are also advertisements covering the field of biology in general. Though the level is high, many teachers will find this journal of interest.

The Institute also publishes a series of monographs which, again of academic standard, nevertheless are of potential interest to teachers where biology teaching is at a high level. Some titles are:

Freezing and Drying
Biology as a Career
The Biology of Deserts
The Numbers of Man and Animals.

Universities Federation for Animal Welfare. 7A Lamb's Conduit Passage, London, W.C.1.

The U.F.A.W. is responsible for a book which should be in every school where animals are reared:

Animals in School is of moderate price (12*s*. 6*d*. st.) and reviews fully most aspects of the care and management of animals for use in teaching.

Publications of the Field Studies Council. 41 Queen's Gate, London, S.W.7.

Field Studies. The recently introduced Journal of the Council, though it deals only with studies in the British Isles, would be found of great value by teachers everywhere. At once a continuous proof that the basis of biological understanding must be biological observation, it is also through the very variety of its articles, a practical guide on how to carry out field studies. Lack of this knowledge is an obvious reason for the relatively poor development of such studies in many schools in tropical countries.

R. F. MORGAN. *Environmental Biology*. Pergamon Press.

This series of books, of which only the first volume is available as this note is written, is for ordinary level School Certificate candidates in England. Despite this the series promises to be of wide interest as an example of a more biological approach to the teaching of biology. The observations and experiments proposed could, with a little modification, be adapted to other conditions. Many teachers who are ready to accept the four 'rules' which I set out on page 35 of this book find difficulty in putting them into action. The book noted here, *Environmental Biology*, should provide them with an excellent model.

Organization for Economic Co-operation and Development. New Thinking in School Biology

This is the Report of the O.E.C.D. Seminar on the Reform of Biology Teaching which was held in Switzerland in 1962. Two points about it may be noted as of especial interest:

a. It is, to some extent, a 'European' presentation which can be compared with the American presentation reviewed elsewhere in this Appendix.
b. It represents the views mainly of professional biologists, who appeared to have outnumbered the 'educational' side of the meeting.

This is an important document which should be available to every biology teacher (especially to those dealing with senior forms in secondary schools) and to the inspectorate and others in the field of educational supervision and administration. It is not a curriculum or syllabus, but it is a fundamental study of the principles which should underlie biological education. Both biology as a subject and education as a process transcend national and regional boundaries and the topics considered by the Seminar are those significant in most parts of the world.

These topics and their arrangement in sections are set out below:

General Theme: The Role of Biology in General Education

Special Themes: Attracting and Training Biologists

i. Biology for the Future Citizen and Future Biologist
ii. The Experimental Approach to Biology
iii. The Reform of Biology Education in Europe

New Approaches to Curricula

i. Reform of Biology Teaching in Teachers' Colleges
ii. The Place of Ecology in Biology Teaching
iii. Mathematics for Biologists
iv. Reform in Universities.

Present Position and Trends Towards Reform in Secondary Schools in Specific Countries

i. A.I.B.S. in U.S.A. Biological Sciences and Curriculum Study

ii. Reports from Delegates
iii. Characteristics of the Required Reforms
iv. Problems of Implementation
v. Ways and Means of Reform

It will be seen that the Seminar covered a wide field, but selected its topics with a sense of reality. Those who study the document will be further struck by its practical flavour for, in connection with most of the themes, there were excursions into the practical consideration of how theory could be put into action. A further evidence of the practical approach was the extensive book exhibition.

In a seminar with many participants from many countries differences of opinion were to be expected. To read of these differences, and to be introduced to different viewpoints, is always of value to the teacher. This Seminar report, which is concerned with differences of approach and opinion, is thus of particular interest and it will appeal to all who really want to improve their knowledge and ability. And it is of particular interest because it reflects the views of academic biologists, and not only those of educationists. It might however have been of value if the Seminar had had at its disposal a larger selection of studies of teaching methods and curricular content in biology. As it was the emphasis was heavily on textbooks and there was only a single recent survey of the 'educational' aspects of the field.

Apparent throughout the Report is an emphasis upon five aspects which have also been emphasized in this Handbook, as also in earlier works by the present writer. These are:

(i) the need to make biology a study of *living* phenomena, processes and relationships
(ii) the need to make biology an experimental science and not a merely theoretical study
(iii) the need to introduce a quantitative as well as a qualitative aspect in experimental work
(iv) the need to study the inter-relationships of biological and other phenomena
(v) the need to see biological education as a contribution to the social education of the individual.

These five points received attention from various aspects and, naturally enough, there was no complete unanimity. What was however a marked feature in every treatment was the strong sense of reality behind every discussion. One evidence of this is seen in the frequent reference to the problems of implementation, which indeed were the subject of a special paper (p. 243 of the Seminar Report). Indeed the critical reader would soon realize that many of the Seminar participants, out of concern for practical problems of implementation, were somewhat sceptical of some of the proposals of American origin. These it seems were thought of as unrealistic on two grounds, that they demanded too many resources and were of too complex a nature—though there is little direct statement to this effect.

The Seminar devoted considerable thought to the construction of the biological syllabus and several examples were offered, in varying degrees of detail, for various educational stages, and mostly with a strong emphasis upon the functional aspects. (See p. 371.)

APPENDIX H

THE BACKGROUND OF BIOLOGICAL EDUCATION

It is now generally accepted that social and economic progress in all countries depends upon an increasing use of technology. This means that development depends upon more than industrialization. The improvement of agriculture, animal husbandry, fishing and forestry, at every level from the cash-crop small-holder to the company plantation, is of great importance. With this in mind attention is now being given to the development of science education in tropical countries. To further this, Unesco has undertaken the series of handbooks for science teachers, of which this is one, as well as having undertaken the sponsoring of science teaching missions.

The physico-chemical sciences are of great importance to the ordinary man and woman in tropical countries. But biological knowledge and the attitudes it can help to build are at least of equal importance. Teachers, therefore, must be persuaded of the importance of biology. Their teaching of the subject must be improved. They must then turn to the background problems which affect both their willingness and their ability to carry out the task. The teaching of biology does not depend only upon the teacher. He must show himself worthy of support from all the authorities. The background problems of science teaching may lie beyond the direct control of the teacher, but they may still directly affect his work. It is the purpose of this Appendix to provide teachers with some guidance on these background problems.

THE TRAINING OF TEACHERS OF BIOLOGY

Secondary school biological science at senior level should be taught by university graduates with educational training. Apart from the fact that these are in short supply, there are also problems of training to be considered. We shall deal with this problem first. In regard to training in the biological field two problems need to be considered.

The first of these is the combination of subjects for the degree. Many schools cannot support two biology teachers, and therefore need an individual who is competent in both zoology and botany. Such individuals of course are not always available, as many students combine one biological science with physics or chemistry or some other subject. Reasonable and desirable as this is, it raises a difficulty at school level. This is due partly to a university requirement that a student shall only follow subjects previously studied to an accredited level at school, and partly to the narrow demands of specialization for university degrees.

This is a problem in need of consideration in any country where it is hoped to expand the teaching of biology in schools. Joint discussions between representatives of the Universities, the Ministries of Education and School Principals would be valuable in finding ways of resolving the difficulties. These might include modification of entrance requirements, intensive courses during vacations to up-grade a student's qualifications, and collaboration between schools to ensure that pupils were able to study both zoology and botany.

The second problem in biological training is raised by course content in the two fields. Universities are concerned with the teaching of various subjects rather than with the preparation of teachers for their career. Courses are designed to meet the requirements of the subject —not those of a particular profession. The result, as noted earlier, is that young graduates may have a considerable knowledge of their subject, but lack much of the background knowledge so important to the teacher, such as techniques of culturing; how to prepare and collect materials; how to set up and maintain an ecological plot, an aquarium or vivarium; how to inject a specimen; how to prepare and mount a skeleton; how to service and adjust their apparatus; how to do simple glass work, etc. All these are services provided, in the universities, by laboratory staff. Few schools have such staff and, as the teacher has no training in these matters, there is a tendency to waste money on what could be collected or made and to leave undone much experimental work which should be done. The result is a general lowering of efficiency.

It is often said that all these things should be dealt with in the courses in Education. But teacher-training departments seldom have the resources which are necessary for such work.

Here again is a problem on which thought and collaboration are needed. It may be neither desirable nor possible greatly to modify the content of the degree course, but as such training is essential, there should be some attempt to provide, for prospective teachers, special courses in laboratory arts and crafts in the field of biology. These courses might be undertaken during vacations.

Until this problem is solved, the professional training of the biology teacher must make up for inadequacies of the kind referred to above. This is not possible unless those responsible for professional training see their task in realistic and practical terms and have adequate facilities. Too often 'biology method' is restricted to theory. This is important, but teaching is a practical task and requires practical training. It is therefore essential for the teacher-training course to provide specific and practical training in the necessary skills where the degree courses fail to do so. There must be a garden, workshop and laboratory at the disposal of the biology method lecturer, though some of the facilities may have to be shared with other sciences. The fact that shortage of money will limit facilities more strictly than in the degree courses is even to the good, for these are the conditions under which teachers work in schools.

In earlier chapters a good deal of attention has been given to visual aids materials and methods. Few today question their value and many are ready to provide them in the schools. They will not be used fully and effectively unless teachers are trained in their use. Here again teacher-training departments are sometimes ill-equipped, and more often fail to make good use of what resources they possess. Those who train teachers must not merely recommend and demonstrate visual methods as something to be used occasionally. They must be used in the training of teachers as part of normal procedure in order to build up a belief in their value and demonstrate that they can be used normally.

In societies where manual work tends to be held in somewhat low esteem, it is desirable, even essential, that teacher-training should not only include some training in the use of hand-tools and the construction of simple apparatus, but also do what is possible to reform attitudes towards manual work. Although many countries have a primarily manual culture, the centralized control of education, and the stressing of primarily academic pursuits in secondary education, results in an over-emphasis upon the white-collar professions. Unless biological education produces some people with a high level of education who go back to the primary industries of farming, fishing and forestry, it will not have made its maximum contribution to society.

During the training of the teacher, attention must be given not only to teaching techniques concerned with the acquisition of information, but also to those concerned with the development of interests, of skills in reflective thinking and of democratic and co-operative attitudes. These techniques are difficult to achieve. In many Asian societies in particular, tradition and custom have given to the teacher a special authority, a position which is recognized by society, by pupils and by teachers. The teacher should indeed enjoy authority, but it should come from prestige awarded in recognition of social and intellectual leadership, rather than an autocratic position. Those who have experience of teacher-training under such conditions realize that here lies one of the most difficult of all their problems. It is this which leads to the all too common type of teaching in which the teacher lectures and dictates rather than teaches, and pupils copy down and learn notes, rather than seeking to understand. There is too little inter-action between teacher and pupil, too little discussion and far too little opportunity for the pupil to initiate action and learn to become responsible by taking the lead.

To achieve a more desirable situation must be a main aim in teacher-training. Its possibility depends upon having available those already dedicated to these views. Where they are not available there arises the preliminary task of training the staff of teacher-training departments and colleges. Such training is given in two ways, by sending staff overseas and by making use of overseas staff. A number of points arise in each case which are worth considering.

THE USE OF OVERSEAS STAFF IN SCIENCE EDUCATION PROGRAMMES

When staff go to an overseas institution it is obvious that they have to fit into an existing framework. Only in places where there are large numbers of foreign students is it likely that the courses offered will be really suitable. As a result many teachers either repeat studies they have already done, or follow courses not suited to their needs. Then also there is the understandable but usually unsuitable desire to work for a higher qualification. The only way to get the best possible return from overseas study is to lay down clear indications of what would be of most benefit to the educational situation from which the student comes. It is that which matters—not the student nor the institution to which he is going. On the whole, despite the difficulties involved, host countries and institutions are very willing to fall in with a reasoned and reasonable plan. Such plans should therefore be prepared with care and imagination and should provide for experience in as many overseas institutions as possible.

The effective use of overseas staff as, for example, Technical Assistance Experts under the sponsorship of International Agencies, raises problems of several kinds. A basic point to which attention should be given when a request for help is made, is the question of a Counterpart. The Technical Assistance Expert, though responsible to his Organization, and the Ministry with which he works and the Institution in which he works, must also have some specific point of contact. This is the Counterpart, who has to carry on, after the Expert leaves, the work he has begun. It is clear that the Counterpart should be appointed early enough to work continuously with the Expert.

The work of the Expert may be considered as falling into two parts. On the one hand he may be concerned with training biology teachers for the host country. To this task he brings knowledge and experience, which of course come from a different cultural setting, and so he has to adapt his procedures, modify methods and so on. At the same time he has to choose between alternatives set before him, and to follow one path rather than another. He does this continuously, in the light of his knowledge and with regard to the new situation in which he is working. The end result is a particular set of procedures which he recommends and practices. It is here that the Counterpart is of such importance, for it is to him that the Expert can impart all the reasoning which lies behind his decisions. The effective provision of Technical Assistance requires not merely the production and application of a particular technique, but the passing on of the reasons which underlie it. For it is this which will be important when the Expert leaves and the host country has to carry on by itself.

While the selection of Technical Assistance Experts is, in the first instance, the function of the Agency concerned, the selection of Counterparts is entirely the responsibility of the host country. The successful Counterpart requires many qualities—dedication to the job, a high level of ability, faith in the task and a tremendous capacity for hard work. The Counterpart should be someone who has already earned respect by his own abilities, for, unless he has the qualities of leadership, he will have few followers. Another important point relates to his status. It is desirable that this should be as high as possible. While a Project is in operation the Counterpart enjoys considerable prestige through his association with the Agency and the Expert. Unless his own abilities and status can preserve this prestige after the withdrawal of the Expert, there can easily be a tendency for a work which started well to slow down, and even come to a standstill.

IN-SERVICE COURSES

In the development of biological education there will arise the need to organize in-service training courses. Teachers need a chance to refresh their knowledge, to bring it up-to-date, to extend it into new fields and especially to reshape their ideas on teaching methods and the task of the teacher.

In the organization of courses of this kind a number of problems arise. Many of these will be concerned with particular situations but others will be more general. It is hoped that the following comments will be of help in both cases.

Careful and complete planning of all such courses is essential if they are to achieve their ends. The first task is to define the end of each such course in narrow and specific terms—even if the general subject matter is fairly wide. It is only when this is attempted that it is possible to prepare a complete list of all the materials and resources which will be required. The most important of these will be the staff to operate the course. It is always wise to have available more staff than will be actively employed, not only as a safeguard against illness, etc., at the critical moment, but also, by calling on both senior and junior staff, to provide some training for staff as well as the potential students. Every member of the staff tutorial group should have specific duties, defined and described on paper and known to everyone. One of the specific tasks should be that of preparing the lists of materials, assembling them and being responsible for their delivery at the appropriate place and time.

Though the aim and content of the course may have been determined by a single individual, for example the Technical Assistance Expert or Chief Inspector, the planning of the course should be cooperative effort as far as possible and, especially where practical work and field-work is involved, the time factor should be carefully considered. Any details involving travel or accommodation should be checked in advance.

A series of briefing papers should be prepared and circulated as a basis of planning and discussion. All accepted plans should of course be duplicated and distributed to all concerned. Every such paper should bear a title or code number for subsequent identification and reference. Copies of all Course Papers should be filed. At the conclusion of such a course a general discussion, in the nature of a post-mortem, might well be held. This should be in two parts. Firstly, at the end of a course, the reaction of the students should be explored by discussion and questionnaire. Then the findings obtained can be gone over at a staff discussion and used to improve future courses. Students should know that their views are used in this way. This is one way of getting over to them the idea of collaboration in working at a joint enterprise.

It is probable that a residential course in which there is more opportunity for informal discussion is preferable to one where staff and students live apart and meet only in class periods. Moreover a residential course makes it easier to organize screenings of educational films at night, without recourse to a blacked-out room. Similarly field expeditions are rendered easier to arrange.

While there is an understandable tendency to organize such courses in a large town or the capital city (a visit to which is naturally enjoyed by those teaching in rural and often remote areas) and in a leading scientific institution, such as the local university (which not only enjoys prestige but also has resources) there is much to be said for holding at least some of the courses elsewhere. First of all, the use of the school as a setting provides a demonstration of what can be done in the school laboratory. Secondly, the holding of such courses encourages the school and helps to improve its work and resources. Thirdly, by holding such courses successively in schools in different places there is provided a variety of ecological backgrounds. These provide experience, knowledge and the opportunity to collect specimens.

EDUCATIONAL METHOD OF IN-SERVICE COURSES

Apart from the content of such courses in biological terms, there will arise questions regarding teaching method. Many aspects of this have been explored earlier in this book. Here it is only necessary to point out that this is, in many ways, the most important of all the problems to be dealt with. It is also the most difficult.

Teachers-in-service have usually reached a stage at which they have dispensed with teaching notes of the kind prepared while in training. The danger is that they may have settled down to a routine which has begun to lose touch with creative and imaginative teaching. Experience with this situation suggests that some part of the course should be devoted to lectures, discussions and practical work concerned solely with teaching techniques. The practical work should take the form of a 'workshop' devoted to the preparation of lesson materials.

The main need is to develop a generalized procedure which can be applied to specific situations. It is usually found that this is difficult as teachers tend to be concerned with their subject matter, rather than with their pupils. Understandable though this is, especially at the higher levels, it cannot be looked on as conducive to good work. Most teachers who have received educational training have devoted attention to the construction of lesson notes. In theory these provide a framework for teaching a particular subject to a particular group. In fact they often become little but an exercise undertaken because it is required. Too often the notes are prepared with little reference to the pupils, the concern being too much with the subject and the 'technique'. Equally often notes are prepared upon some fixed plan with too little reference to the many variable factors involved. A final fault in the situation is that notes are prepared but not discussed with a tutor whose experience could help to avoid mistakes before they find their way into the class-room. Perhaps it is natural that teachers soon begin to feel that they no longer need lesson notes to guide their work, but the longer they can be persuaded to make use of good notes the better teachers they are likely to become.

A common scheme for lesson notes is:

1. Statement of aim . . .	to teach so-and-so
2. Introduction . . .	résumé of earlier work

3. Development	presentation of theme or content
4. Application and Fixation	exercises for pupils
5. Recapitulation	questions and test

Such a scheme is likely to be accompanied by a note on practical work, on illustrations to be used, and so on. However, while it is simple and gives confidence to the young teacher (a very important point), such a scheme, and many like it, are open to various criticisms.

(*a*) The set-out is almost entirely subject-centred, with very little reference to the pupil, other than as one expected to carry out instructions.
(*b*) There is no built-in demand for the teacher to be critical of himself, so that he proceeds only in accordance with his plan, not in regard to his success in teaching what he is attempting.
(*c*) There is little, if any, reference to the possibility that pupils' interests may develop in various directions and that this should be exploited, both in the class and afterwards.
(*d*) The teacher's part is defined only in regard to his plan, with no indication as to how he might proceed in the light of pupils' interests.

It is to overcome the somewhat limited attitudes inherent in such situations, which are derived from a whole complex of causes going beyond training to previous school experiences, that it is suggested that every in-service course should include time given to lesson construction. Such time may be utilized in various ways. Experience suggests that the following might well be included:

(*a*) A discussion period, aimed at the formulation of guiding principles for teaching which should be reflected in lesson-notes.
(*b*) The examination and analysis of a series of prepared lesson-notes, to determine how far they fulfil the principles derived earlier.
(*c*) Practice in the preparation of lesson-notes:
  (*i*) As a group activity—in small groups;
  (*ii*) As an individual activity.
(*d*) The critical examination of notes prepared by groups and individuals.

A practical follow-up of such work is obviously desirable. This must be done when the teacher is back at school and it should be accompanied by a critical evaluation—which can be used as case-study material in future in-service courses.

It may be of interest to add a brief analysis of a generalized scheme for lesson-notes which is the outcome of the writer's work, along these lines, with biology teachers attending refresher courses.

SCHEME FOR A TYPICAL LESSON-NOTE

1. *Statement of the specific aim of the lesson*
   (topic, unit, etc.) and examination of its relationship with what has been done earlier and what will be done later.
2. *Statement of materials to be used, etc.*
   Apparatus, teaching materials.
   Proposals for experiments, expeditions.
3. *Exploration of children's knowledge and experience*
   What are pupils likely to know from formal teaching?
   What may they know from informal sources?
   What relevant experiences may they have had?
4. *Difficulties to be anticipated*
   (*a*) Lack of knowledge—absence from school, etc.
   (*b*) Perceptual difficulties—lack of skill in 'seeing'—'feeling'—perceiving.
   (*c*) Conceptual difficulties—topic may be too complex, children may lack experience, some may be insufficiently intelligent.
5. *Proposals for overcoming difficulties*
   A main point here is to realize the nature of the difficulty—otherwise it is unlikely to be overcome.
   Exploratory questioning to locate and define difficulty.
6. *Plan for lesson procedure*
   (*a*) *Résumé* of earlier work—questions, recognition, etc.
   (*b*) *Definition* of new topic—as extension of (*a*)
   (*c*) *Significance* of topic—importance in itself and as leading on to (*d*)
   (*d*) *Presentation* of topic—as a PROBLEM to solve
   Questions as to how we can try to solve it.
   Collect answers—classify as (*i*) suggestions . . . 'it might be' (*ii*) statements . . . 'it is . . .' (*iii*) evidence . . . 'I saw . . .'
   Expand as needed—offer evidence—models, charts, etc.
   Avoid the tendency to tell the answer.
   (*e*) *Activities* . . . experiments, observations, collections, etc., in school or at home.
   (*f*) *Analysis*. What have we found out?
   What are we *certain* about?
   What *may* be true?
   What final statement or proposal can we make?

(*g*) *Recapitulation.* What did we set out to do?
What have we done?
What remains to be done?
Who will do it?
When will they produce results?

(*h*) *Post-Mortem.* Did it go as you intended?
Did you attempt too much or too little?
Did pupils get what you intended?
If not, was this your fault, or theirs?
What pitfalls are to be avoided?
How could the lesson be improved?

All this may appear self-evident and simple to the experienced teacher, but this is the kind of help which is needed by most young teachers. It cannot be given only as advice. It must be backed up by practical work, by individual effort and by involvement in the issue as a whole.

ACTION RESEARCH AND TEACHER-TRAINING

Action research, in the field of education, aims at the improvement of teaching through the co-operative study of an existing situation, by those involved in it. The essence of the situation is the development of a sense of personal responsibility.

Those who are sensitively aware of educational situations do not see teachers as cynical performers at a low level, but as people whose efforts and efficiency are waiting to be tapped by the sympathetic co-operation of those who can provide leadership. Working against difficulties, often in comparative isolation, many teachers feel that they are the forgotten people. They are usually ready to throw themselves into very great efforts the moment they are encouraged in an appropriate manner.

Action research is a useful means of stimulating interest and encouraging effort. It should be an important function of the Training Colleges and the Inspectorate to take a lead in developing suitable forms of action research. This, however, is not possible unless they have the time and resources for such work, and the active support of the central or local Education Officer.

Any form of action research should be developed as naturally as possible, and should appear as something which has arisen from the teacher's own interests. To seek to 'lay-on' a highly centralized scheme is to court failure, because it will appear as an extra imposition on one already overloaded with work. Let it develop from the teachers, let them feel that it is theirs, and at once a sense of involvement will be established which will do much to ensure lasting effort and success.

Suitable times for this kind of activity are to be found especially during refresher courses, in-service work and the like. Once the problem has been isolated and defined, discussion can be centred on how it can be solved. These discussions, by leading to active and critical thought, and to reading on the subject, are themselves of considerable educative value, perhaps more valuable than all that has been attempted in the formal work of a course.

What is attempted, how it can be attempted, and what is achieved depend on local conditions, and to attempt to offer a framework for such work is almost impossible. The basic principles are that such work should be the result of voluntary co-operation, that individuals should choose to undertake work in which they have a particular interest, and that their position as experts should be recognized. It is this sense of recognition which is so important in raising the teacher's estimate of himself, and the higher this is the greater will be his efforts in his work.

In the writer's experience action research is a valuable aid in the conducting of refresher courses. It has been used in a number of ways of which a few examples are given below.

THE CHARACTERISTICS OF THE GOOD TEACHER

Working with a group of about 100 young untrained men and women, about to start on a training course, a series of questions was drawn up (largely by informal discussion) which aimed at exploring their ideas about the qualities of the good teacher.

The questions were in some cases presented in the form of multiple choice items, in some cases as normal questions. Some examples of the former are shown below:

(*a*) Complete in the appropriate way whichever statement describes your biology teacher at school—
My biology teacher was
interesting because ....
successful because ....
popular because ....
dull because ....
unsuccessful because ....
unpopular because ....

(*b*) By writing 1, 2 or 3 against *three* of the items below show which you consider to be the most important qualities of a good science teacher—
To be enthusiastically interested in science ....
To be well informed about science ....

To be good at practical work ....
To cover the syllabus completely ....
To be a neat and tidy worker ....
To be interested in boys and girls ....

Groups of students analysed the answers and the findings were then used as material for discussion. The group leaders (staff of the Course) started off the discussions, when necessary, encouraged students to analyse themselves, and suggested that they should build up a model concept of the good teacher as something to aim at in their own development.

THE DETERMINANTS OF SCIENCE TEACHERS' PRACTICES

It is characteristic of books on the teaching of biology and of lectures given on this subject to teachers-in-training, that they include emphasis upon practical work, field-work, collecting, keeping aquaria, using the library, seeing films and the like. It is also known to all who have a wide experience of teaching that not all teachers actually practise such things in their work. In some cases there are unavoidable limiting factors which bring about this situation. In other cases, where these limiting factors appear to be absent or negligible, the same situation exists, largely because of the attitudes of the teachers concerned.

Identification of the self with an ideal or model presumably occurs among teachers, as among other groups. In fortunate cases this ideal or model sets a desirable standard of efficiency and level of enthusiasm. More often our young would-be teachers lack such inspiration and, with limited experience, they fall back on the humdrum picture of their own school-days to guide them in what they do as teachers.

Action research, since it develops a sense of personal responsibility, appears to offer some solution to this problem. Thus, in working with a group of a hundred young men and women, it was decided to seek to widen their experience and improve their general practices as science teachers through action research.

In this instance, by the use of questionnaires, the following aspects of their previous experiences as pupils were explored:

1. *The relationships between pupils and teachers.*
   These were investigated along four lines.
   (*a*) Qualitative rating of their previous school teachers by the group.
   (*b*) Quantitative rating of these teachers by the group.
   (*c*) Listing of approved qualities among their science teachers.
   (*d*) Extent to which teachers had encouraged or discouraged pupil interests.

2. *Experiences as science pupils.*
   - (*a*) These were investigated with regard to adequacy or otherwise of provision for practical work.
   - (*b*) Encouragement of extra-curricular work in Science.
   - (*c*) Guidance in the choice of Science as a school subject.
   - (*d*) Motivations in the choice of teaching as a career.

The attitude of teachers was dealt with by the group as in the first example. Discussion made it very clear that the experience of being involved in even so simple an example of action research had greatly improved the students' understanding of his job. Many who had limited experiences as pupils said that as teachers they would seek to offer greater encouragement and wider experiences to their own pupils. Events have subsequently shown that in a high proportion of cases this prediction is being fulfilled.

PUPILS' UNDERSTANDING OF SCIENCE CONCEPTS

The usual method of evaluating science teaching is the essay type examination. Criticism of this method is common and new types of tests have been developed in the search for improved evaluation. Among the possible outcomes of science education is the danger that children will 'know' science, but not be able to use it, that they will tend to remember, but not to understand. Even where they can use their skills it is in the setting of a familiar situation. Faced with new problems, or even with old problems in a new setting, they fail to solve them because their knowledge and skills have remained specific, instead of having become the basis of a generalized approach, applicable by adaptation to novel problems and situations. It is a salutary experience for the teacher to realize that the results of his teaching are more limited than he expected. Moreover, it is only with such experience that he is able to locate difficulties in the learning situation and seek ways of overcoming them, by improving his teaching methods.

An initial attempt in this field of science education was made with groups of teachers-in-training, a group of young entrants to the profession and a group of scholars. Two techniques were used.

In one case the teacher groups built up a list of words, each dealing with a common idea in Science and all used in the vocabulary of science teaching in school at post-School Certificate level.

They included such words as:

fact
evidence
detail
experiment
classification
principle
observation
control
reliable
sensitive
variation
hypothesis

The teachers in the group were asked to indicate which words would be understood by all pupils, by most pupils, by some pupils and probably by no pupils. The pupils were asked to write brief *definitions* of the words, as used in science. The results were analysed, compared with the teachers' predications and discussed by the teacher groups. Many members agreed that the results made it clear that there is a difference between 'knowing' in the sense of remembering, and 'understanding' in the sense of being able to explain and use. Some of the group made suggestions as to how the situation could be improved. All expressed the intention of trying out these suggested improvements.

In the second case the same list of words was used but they were presented as multiple-choice items, and use was made of both English and the pupils' own language. The results in this case gave a measure of the extent to which language was a barrier to understanding. Again there was evidence that the experience of this simple study gave to the teacher new understanding of his problem of communicating ideas to pupils.

The outcome of action research in education depends upon many factors which have been summed up in the term 'involvement'. It brings the teacher into a functional relationship with other teachers and with the Inspectorate; it helps to preserve his contact with his Training College and it also provides opportunity to be creative. In brief, it provides a new status, a feeling of acceptance and the satisfaction of achievement. The more of this that we can achieve the better will teaching become.

A MOBILE TEACHING UNIT

Just as mobile libraries have been developed as one means of furthering education under the kinds of condition typical of many Asian countries, so too there is a place for a Mobile Science Teaching Unit. This is to be considered here in relation only to the biological sciences.

The function of such a Mobile Unit would be to help to improve teaching in every way possible by providing demonstration of materials, methods and methodology. This function would be fulfilled in two main ways:

(*a*) By acting as an ancilliary to all short courses.
(*b*) By providing demonstration and training as a travelling unit.

The setting up of a Mobile Unit requires:

(*a*) A suitable motor vehicle chosen in relation to function and local conditions. The body of 'caravan' type should contain:

Projection equipment (16 mm. movie, strip and micro-projectors)

Work bench and *tool kit* for training, demonstration, maintenance and repair work

Teaching aid material related to the subject and chosen to illustrate what is available by sampling rather than seeking to show everything

Specimens to illustrate both biological principles and methods of preparation, display, etc.

Examples of *reference* and *class books*, including some general 'background' reading in science

Collections of *catalogues* of books, visual materials, apparatus, etc.

Small *supplies of standard materials* to make up deficiencies in school laboratories

Small *supplies of 'spares'* (projector bulbs, etc.)

It will be necessary to consider the design of storage spaces with care, both in order to avoid damage and also to permit rapid and effective use of resources. Thus, where it is necessary to pack items into boxes, these should be of such a kind that when opened up they act as display cases. The dimensions and construction will need to be standardized, so that materials for various topics can be stored in the basic standard containers.

(*b*) Academic staff. This should include either a teacher or inspector seconded for special duty and able to turn a hand to all aspects of the teacher's job, for this is something to be done, not merely talked about. At one moment it will be a question of showing how to service, set up and make effective use of a microscope or projector, at another how to teach genetic principles or dissection. The academic staff should, if possible, number two. One, more senior, on the job for a period of two or three years. The second, attached for a term or a year, and so being trained either to take over the Unit or to go back to school a better teacher than he was at the start.

(*c*) Technical staff. Conditions doubtless vary but in Ceylon (for example) such a Mobile Unit would have a driver and a cleaner. If these men can be persuaded to do a little more, to help work the generator and projector, or to do some simple mechanical work, so much the better. If not, there should be a trained technician. Here again is the chance to give some training to school laboratory attendants.

(*d*) Headquarters staff and resources. Leaving out the purely administrative aspect, it will be necessary to provide control and direction as well as resources. The control and direction could come from a Science Inspector. The organization of supplies, changes of the 'content' and the like, demand a depot for maintenance and supply. Most education authorities have a department which services their vehicles, but in this case more is needed.

Supporting a Mobile Teaching Unit there must be an adequate organization to ensure efficient use of the Unit. It must, for example, be the function of an Inspector to plan the work of the Unit in conjunction with his colleagues, the schools and the training colleges. During school terms the M.T.U. would relate its activities to school programmes. During vacations, when teachers are free, it would operate in conjunction with In-Service Courses. As it should be in operation as long as possible careful planning will be needed to limit the time spent on servicing the vehicle and reorganizing its teaching collections. Similarly a system of reliefs will need to be worked out to provide leave for regular staff, while keeping the Unit in operation.

Such a Mobile Teaching Unit might also do much to help the Museum Service, acting as an agent for the distribution of its Loan Collections. Similar help might be given in connection with Library Book boxes. Moving about the country continuously the biology teacher (or teachers) associated with a Mobile Unit should be in an excellent position to act as specimen collectors. If they can also take photographs of appropriate things so much the better. Both activities would add greatly to the resources of the Science Centre referred to below.

A SCIENCE TEACHING CENTRE

There is much to be said for the development of a special Science Teaching Centre which would

(*a*) act as a central *Science Store* into which all science materials would come and be distributed to the schools. This should be backed up by an adequate system of indenting and ordering so phased as to spread the load of work over the school year and so operated as to prevent any hold-up through shortages.

(*b*) act as a *Maintenance and Repair Depot* under the charge of a Technician. Apparatus in the schools should be inspected by the Mobile Unit staff and, where repairs are beyond their resources, the apparatus should be sent to the Centre. As the Technician in charge will be called upon in at least three fields of science, he will need to be specially trained (it may be noted that this was effected in Ceylon with the aid of U.S. Aid, as was much other training).

The Technician should be competent to help with the training both of academic teaching staff and for their laboratory assistants. The frequent charge that apparatus is neither made nor repaired in the schools results partly from the fact that so little is done to make it possible. The provision of suitable in-service technical courses at the Science Teaching Centre would greatly contribute to science teaching.

(*c*) act as a central location for all forms of in-service courses in science. While it has been pointed out that these should be held in schools, and in the provinces as well as the capital, there will always be special demands for central courses. Under ideal conditions there would be a resident or permanently attached Science Inspector at such a Centre. There would be need for rooms of several kinds as well as laboratories. Thus there should not only be large classrooms, but also smaller seminar rooms.

(*d*) act as the centre of a *Science Library* which would provide services to pupils and teachers for both loan and reference. To meet provincial needs a book-box system should also be operated. Teachers are often charged with being out of date, but this is almost unavoidable where they have no library facilities. In Ceylon the book-box system in the field of science teaching is operated through the Inspectorate, but it is planned to centralize it in the Science Centre when this comes into operation.

(*e*) provide a *Visual Aids loan service* in the field of science. Many Asian countries have set up Visual Aids Services based on travelling vans taking film programmes from school to school. Valuable as these services are, they are usually not closely integrated with the actual teaching programmes. This can only be achieved through a well-organized loan service with adequate resources and a well-trained staff in control.
This staff would be mainly clerical but there should be a Visual Aids Officer who could also operate training courses within the Science Centre.

(*f*) provide a centralized *Scientific Museum service* to the schools. Museums are little developed in Asia and, even where they exist, they usually lack a modern scientific section and have little contact with the schools. Even a single exhibition hall would be of value, but the service would be still more valuable if a loan-box system could be operated.
Here again the officer in charge should be competent to conduct training courses for school staff, both in technical museum work at school level and in the more educational aspects.

Proposals of this kind may, at first sight, appear unrealistic, but in fact they are essential to the efficient development of science education. Such a Centre would be of the order of size of a training college. Though likely to involve greater initial capital costs the recurrent expenditure should be less.

BIOLOGICAL SUPPLIES

The provision of the raw material used in biological education presents problems different from those associated with the supply of, say, chemical reagents. Biological materials may have to be collected or cultured, their normal habitats may be remote and difficult to reach, the material may have to be preserved or prepared in special ways, or kept alive pending delivery to the school. These conditions present a number of difficulties to which too little attention is given. As a result much teaching is done with the aid of diagrams rather than specimens.

In earlier sections, where reference has been made to the school garden, the vivarium, the aquarium and methods of collecting, some suggestions have been offered which should help teachers to overcome some of these difficulties. However it is clear from common experience that even the most willing of biology teachers cannot provide all that is needed. It is necessary to consider the provision of biological supplies, in particular the supply of specimens.

One source, the most widely used, is the commercial supply agency. Many firms provide very efficient help but it still remains difficult to obtain certain kinds of specimens, and usually impossible to obtain any in the living state. Then again delivery takes time, and freightage, packing and insurance add to costs which are already high, while school funds are usually low.

It is therefore necessary to consider what can be done to overcome these difficulties. First of all the teacher and his classes should do all that is possible to collect, preserve and prepare materials. Use should also be made, if possible, of the Mobile Unit.

The next thing seems to be to exploit any other likely sources, such as a local botanical or zoological department or the parks department, if such exists. Attention might also be given to any local Natural History Society, Gardening Society, etc. There are often, in the larger towns, many such bodies from which help can be obtained.

Lastly comes the question of a Biological Supply Depot. To set up such a depot is a major undertaking and one which has many implications, especially financial ones. The possible reaction of trade suppliers may also have to be considered. It is doubtful whether such an undertaking could be an economic proposition, as an independent unit, unless the potential demands were very considerable. On a smaller scale however it could be part of the Science Centre.

It would be necessary to have a laboratory equipped for such work together with technicians able to deal with zoological and botanical material. Materials would be obtained by purchase (e.g. dogfish from the fish market) or collecting (schools in different districts might contribute here) and by culturing (e.g. Paramoecium). The technicians would prepare materials, or merely preserve them, and also make slides and mounts, etc. It would also be necessary to organize a dispatch section to handle orders.

Though this is an activity which has not been thought of as a responsibility for the Education Authority it is, nevertheless, one which is very important. At present the lack of materials is, in many places, a big factor in reducing the efficiency of teaching of botany and zoology.

A SCIENCE INSPECTORATE

A well-trained specialist Inspectorate is essential to the successful operation of science education. Three basic conditions however must be fulfilled:

(*a*) This Inspectorate must be concerned with the problems of science education and not be allowed to dissipate energy in the mass of trivialities which so easily multiply, to the exclusion of what really matters.

(*b*) The Inspectorate, despite the status and dignity of their name, must see their function as that of actively and co-operatively helping to improve science teaching. It should be their task not to pass judgment, but to give help.

(*c*) It must be realized that no one can inspect or offer effective help in a field over which he does not have a considerable command. The Inspectorate must be based on those whose ability, training, experience and personality are such as to make them leaders whose leadership will not only be accepted, but sought.

There are no points in a science education scheme at which the Inspectorate is not of paramount importance. They are the link between Administration and Education, and between Capital and Provinces. It is they who must know the teachers and their problems, who must help in the training (especially the in-service training) of the teachers and who must be continually up-to-date in their knowledge of both science and education.

The building up of a Science Inspectorate is far from easy. Suitable candidates are none too frequent and, after selection, their training also provides problems. So far as this is concerned, reference may be made to the procedure followed in Ceylon. Some nine men and women were selected as being potentially suitable. On appointment they were posted to schools and required to do a normal teaching job with a strong emphasis on lower school work. After a term of this they were then given charge of some section of the senior science work in their own school as well as supervisory responsibility for elementary science in two or three other schools. Finally they spent a term with supervisory responsibilities only. During the whole period they both attended courses (in vacations) as students, and were responsible for teaching in other in-service courses.

At the same time two or three more senior inspectors, who had worked both in the field and in provincial education offices (and in one case in the H.Q. office) were sent overseas for training and to gain general educational experience.

In all cases each officer was expected to extend his knowledge of science into fields other than his own. Thus some, already qualified in physics or chemistry, found themselves following biological courses.

INSPECTORS AND TEACHER-TRAINING

There has come about an unfortunate division between various aspects of education whereby many of them have lost contact with each other. In particular, this applies to teacher-training and the Inspectorate. The former, conducted in Training Colleges and Departments, is in the hands of a staff unavoidably disassociated from the schools. The Inspectorate, closely in touch with the schools, has limited, and in some cases no, contact with teacher-training. This situation, partly as a result of increasing administrative complexity, is also partly due to the fact that the Inspectorate is viewed as a Police Force rather than as a Welfare Service.

The experience of those actively engaged in building up a comprehensive science education service suggests that this unfortunate division should in some way be remedied. One way might be to ensure that every training institution had the part-time services of at least one of the local inspectors, and that all newly appointed teachers were under the special educational guidance of members of the Inspectorate during their first year of teaching.

EXAMINATIONS

The organization and conduct of school examinations is unavoidably complicated and extensive. As a result it has become common for special 'Examination Branches' to be formed, which often possess a considerable degree of autonomy. While there are grounds for ensuring that the examination section enjoys some identity of its own, so that it may be free of prejudice in its task of evaluating the work of the schools, this should not give it authority to determine the work to be done in schools.

In effect this is the position sometimes reached. In such a situation what goes on in schools no longer reflects a considered view of education which has been embodied in the curriculum and syllabus, but instead has become bound to what is 'set' by the Examination Branch. Such a position cannot fully be justified on any grounds and certainly cannot be sustained on purely educational grounds.

The function of examinations is to evaluate the efficiency of the educational system in relation to an agreed curriculum. It is therefore essential that those responsible for drawing up and teaching the curriculum should have a major responsibility in the conducting of internal examinations. This situation is seldom achieved by the common device of having 'one or two teachers' to guide the Examination Branch. Teachers, College Staff and School Inspectors should all be represented and have effective power.

In particular, they should give attention to points raised earlier in regard to the testing of understanding and the ability to use knowledge, as distinct from the ability merely to remember it. To re-model examinations along these lines is not an easy task and perhaps this is why it is so seldom attempted. It is however possible once the need to do so is appreciated and the methods of so doing understood.

The most important point to realize is that examinations measure the efficiency of teachers as well as pupils. Where performance is poor, it is usual to blame the pupil for not having worked hard enough. That may indeed be a factor, but the teaching of the subject must also be considered. Moreover attention must be paid not only to the teacher and his work, but also to the provisions, backing, support and encouragement which should be provided for him by the Inspectorate and the various services needed to support science education.

SCIENTIFIC SOCIETIES

In those countries where education and science are advanced and well organized, there exist organizations which are of particular benefit to science teaching. Museums, Learned Societies and industrial firms, for example, sponsor the production of materials ranging from picture post-cards, through films, up to large-scale exhibitions. In addition they also frequently organize science lectures and demonstrations for school pupils, the most famous example being the Popular Lectures of the Royal Institution in London.

In many less advanced countries such amenities and opportunities are lacking. In view of their potential value attempts should be made to develop such opportunities. The sphere in which a Government can take action is, however, clearly defined, and is not large enough to provide all that is desirable as a background to science teaching. However it can, by indirect means, be greatly extended.

Teachers should be encouraged to form Science Teachers' Clubs or Associations which, wherever possible, might be affiliated in some way to any already existing Scientific Association. It is true that the purposes and levels of such organizations may appear very different, but there are two points to note. Each, in its own way is contributing to the development of the country. Any move which will enhance the professional status of the teacher is likely to improve education and increase its efficiency as a factor in general development. The importance of a Science Teachers' Club lies in increasing the interest of teachers in their subjects. For if teachers are interested, so also are their pupils likely to be.

One method which has been explored is the associating of Teachers' Science Clubs with suitable fields of research carried out on a national basis. It is much more possible to achieve this in the biological aspects of science than in any other. It is in relation to survey work and simple field experimentation that opportunity would appear to lie, and it is here also that students themselves might participate with benefit to their own interests and knowledge.

This idea is worth exploration wherever attempts are being made to extend and improve science education. It can be anticipated that the idea might well meet with criticism, if not with opposition, but the difficulties are more imagined than real. Discussion with representatives of several learned societies in different countries has shown that many of them would welcome such a relationship. Moreover it would provide some outlet for the rather vague interest in 'research' which many young graduates claim to have and which is often the reason for them declining to take up teaching, although they often get little chance of research in the alternatives they choose.

There are also international scientific bodies, with interests in education and biology, with which a Teachers' Biological Association (or individual members) could make useful contact. One or two of these publish journals and other materials likely to be of value in teaching.

TEXTBOOK DESIGN

The provision of an adequate supply of books in a variety of national languages is a problem confronting the educational world in many countries. While the basic problem is often largely economic, there are many other aspects. Attention has been given to some of these earlier and some suggestions made as to how the situation might be tackled. One further point is to be discussed here.

Considerable advance has been made recently, even within the past twelve months, in the development of materials for use in connection with 'teaching machines'. Many people have somewhat uninformed opinions about these devices and not a few appear to think of them as combinations of tape-recorders and robots. In fact they are basically a device for presenting material to be learned step by step, and requiring a response from the learner which makes clear to him whether or not he understands the material. The mechanics used may vary, but there is always the basic common factor of presenting the material in a series of steps called a 'programme'.

These steps are based not only on the subject matter, but on the thinking involved in understanding it. Thus the whole content of a syllabus has been broken down into units of learning. Not units in the sense of topics or projects, but units in the sense of steps in reasoning. Teaching materials are, in this way, presented in steps which are based upon the process of learning as applied to a particular subject, not purely on the subject content. The learner is continuously required to solve a series of problems, not merely to remember a series of facts.

It is this situation which is needed in science education in order that the learner may obtain from it far more than the mere acquisition of information which has for so long been the main aim.

The preparation of materials in this manner, so significant for education in science, is not an easy task, but it is a very important one. However it appears doubtful if the methods suggested earlier would be adequate for the preparation of teaching materials, especially textbooks, based on the approach now under consideration. They may be adequate in so far as the content as a whole is concerned, and they may help to improve the physical presentation of the book, but a new psychological approach would demand other things. Some of these, such as a detailed knowledge of pupils' experiences in the field of science from the informal angle, their interests and the factors which motivate them and their methods of learning would require new investigation in the specific situation in question. There would be differences resulting from differences of culture, economic and social background, and also those which are the result of the rural as opposed to the urban background.

Information on these, and other related topics, all of importance in the preparation of teaching materials, could come only from special study. In brief, educational research is vitally necessary for science education. (Reference is made to this in the next section.) So far as the provision of textbooks is concerned the demand is so urgent that there is little chance of awaiting the conduct of fundamental studies as a pre-requisite to book production. However the matter is of such importance that something should be attempted in the way of improving on the normal procedures.

Thus where such a problem exists a call could be made for advice and certain kinds of help from Unesco, under whose aegis attention has been given to various aspects of this problem. The problem is concerned with various fields, learning-theory, communication-theory and semantics. Help could be sought in reference to suitable guidance reading in these fields as well as to specific studies in text-book construction.

RESEARCH ON SCIENCE EDUCATION

Education has progressed largely by means of convictions, hopes and enthusiasm tempered here and there by contact with reality. In today's situation, in which population pressure, shortage of time and economic demand are all important factors, enthusiasm can no longer be accepted as a sign of efficiency. It is necessary to achieve results quickly and as cheaply as possible. In brief, education has become a field for operational research.

Unfortunately the pressures are such that the administrator and planner has no time to await the findings of research. The result is that, in the best of faith, we continue with old methods, even when common experience suggests that better alternatives are available.

There will be little real improvement until the conducting of evaluatory research is seen as an essential concomitant of educational planning and procedures. Such research will have to be on a scale which makes it essential that it lies in the control of the central authority.

At the lowest level there is opportunity for fairly simple studies in costing. The education bill is often among the largest items of public expenditure and any economies which can be effected without loss of efficiency would be welcome. It would then be wise to institute such studies which, however simple and unacademic, are likely to be economically worth while. To suggest topics is hardly possible because every aspect is worth attention. However, a few examples may be given.

The rates of consumption of materials (reagents, stains, specimens, etc.) are far from clearly known. The only definite fact is that there exists a tendency to over-order. If the rates were known it would be possible to rationalize the supply system, with benefit to the budget.

Considerable economic loss is occasioned by the effects of high temperature and high humidity on apparatus, especially on optical parts, such as microscope objectives and eyepieces. Very little seems to be done in the way of protective storage and maintenance, largely because it involves further expenditure for air-conditioning, desiccator jars, desiccants and the like. Again it might be a profitable exercise to compare the economics of traditional losses against protective investment.

Many biological techniques involve relatively expensive reagents, such as alcohols for the dehydration of sections. There are now available improved techniques which reduce the call on expensive materials and often lead to greater permanence. Here too is a potential field for saving.

Though time-and-motion or work studies appear to have little place in education, ideas derived from them might provide certain leads. The organization of the laboratory, of the timetable and of school life in general might well prove susceptible to 'streamlining', in a manner which would allow a more economic use of time.

It is, however, in regard to pupils and teaching that there is most opportunity for research aimed at improving the level of education.

The question of selection at once comes to mind. While it has been argued that all pupils could benefit from some biological education, it seems clear that only those with certain aptitudes can make the best use of the opportunities of specialization. We know very little about these aptitudes, and our biology students too often tend to be those who have some ability for drawing, little skill with apparatus, less in mathematics, and parents able to pay for a potential medical training. This (even if a little overdrawn) cannot be considered as a sensible way of using human resources. The answer seems to lie in some kind of selection, and for this we need research.

Throughout this book it has been a main thesis that biological education has a significant contribution to make to society. The effectiveness of biological education in terms of quantity can be estimated easily, by the number of those with qualifications to enter occupations and professions where a knowledge of biology is needed. As to the quality of biological education, however, we have little to guide us. Few are likely to think that education in general fails to make a contribution to social progress. We should, however, attempt to find out also whether science education in general is making a specific contribution, and whether biological education in particular is helping to produce people who are more productive in their farming or fishing, more hygienic in their habits, more socially responsible in their attitudes. We can know none of these things without instituting an evaluatory programme of educational research.

This is a complex subject, and here, too, help could be obtained from Unesco, at least on the broad principles involved. Though the universities are among the chief agents in the development of this research, they have their limits, which tend to turn attention to short-term problems. Evaluation, however, is a long-term problem which involves many factors. Hence the need to turn elsewhere for help. In the countries of Asia, for example, even in the universities research of any kind is limited in its applications, being confined to narrow and specialist fields. What is needed is something bigger and wider. We need to concern ourselves with the social effects of education, not as an academic exercise, but because we are seeking to use education as a tool of 'social engineering'. Biology, as a part of education, is being used to form attitudes and shape society. We need to know whether we are in fact doing what we think we are. It would be worth knowing the answer in economic terms, and it may be essential to know the answer in the interests of survival.

In view of the significance of biological knowledge to society, of the part played by biology in education and of the costs involved, it would seem that the basis of the whole situation should be the setting up of an Educational Research Unit working on as wide a front as possible and in conjunction with a UNESCO Social Research Centre. This would facilitate evaluatory studies on a wide basis and a long time scale.

APPENDIX I

BIOLOGY SYLLABUSES

G.C.E. Biology Syllabus, Ceylon Government Department of Examinations

The syllabus set out below should be of interest for a number of reasons:

(*a*) It is a direct outcome of the Unesco Science Teaching Mission in Ceylon.

(*b*) Those directly concerned in its preparation were largely trained within the framework of ideas put forward in this book, and particularly those expressed in the discussion of the Background of Biological Education.

(*c*) Associated with the syllabus is an extensive scheme of teacher training of which a major function is the re-orientation of attitudes away from the particular to the general and from memorization to understanding.

(*d*) The new attitudes in teaching are carried over into the sphere of evaluation so that examinations will seek to explore the understanding of principles, processes and applications by demanding the solution of problems rather than the reproduction of learned material.

The stated aims of the syllabus, as it reflects understanding of the purposes of biological education, at this stage are:

(i) An understanding of the facts, principles and theories of elementary biology (as set out in the syllabus below).

(ii) An appreciation and an understanding of the relevance of elementary biological facts, principles and theories to everyday life.

(iii) A simple appreciation and an understanding of experimental science as applied in elementary biology.

(iv) A familiarity with simple apparatus and experimental work.

(v) A familiarity with simple common organisms—animals and plants.

In the syllabus topics marked with a plus sign are to be treated in a simple qualitative manner. Simple models, analogies and graphical representation alone are to be used where relevant. The examination will test only a preliminary recognition of these concepts.

The general aim is to study broad biological principles. Personal observation and use of the hand lens is to be encouraged. Where a microscope is essential the letter (m) is entered beside the topic.

The use of elaborate drawings and floral diagrams is not expected.

An elementary knowledge is assumed of the simple behaviour of solids, liquids and gases in so far as they have a direct bearing on the study of biology.

Content

Nature and scope of biology including a preliminary study of characteristics of organisms—plants and animals.

Plants as primary food producers; structures and form of leaves (m); leaf arrangements, chlorophyll. Conditions necessary for photosynthesis; photosynthetic reaction dealt with elementarily as the primary energy source for organisms; study of the limiting conditions for photosynthesis.

Foods—the constituents of foods; food types, carbohydrates, fats, proteins; simple tests for the identification of the food types and sources.

The structure of the alimentary canal and connected glands of a mammal (rat), its relationship to man. Digestion in the alimentary canal of carbohydrates, fats, and proteins. Activity of enzymes in plants and animals.

The study of diffusion leading to an understanding of the absorption of water, osmosis, absorption of the foods into the animal organisms, absorption of mineral nutrients to plants. +Selective absorption.

Conduction of water, mineral nutrients and organic foods in plants; xylem and phloem tissues and arrangements in monocotyledenous and dicotyledenous plants (m); ascent of sap; active and passive absorption.

The circulatory system and its functions in a mammal (rat). Structure of heart and functions. Differences between veins and arteries (m); blood, constituents and functions (m). Relation to man.

Respiratory system and functions in mammals; absorption of oxygen in plants; oxidation of carbohydrates; fats and proteins in plants and animals; anaerobic respiration, fermentation, +Glycolysis and energy reserves in animal cells. Necessity of mineral nutrients for plants and animals. +Vitamins; necessity and the sources of vitamins in common foods.

The fundamental facts of elimination of wastes in plants and animals including the excretory system of animal (rat), relation to man; the skin of mammal and other common animals (m); gaseous wastes in plants and animals, removal of water in plants and animals, guttation and transpiration, ways and means of minimizing transpiration.

Release of heat as product of cellular respiration in plants and animals; cold-blooded and warm-blooded animals; relation to their structure. +Calorific values of foods. +Basal metabolism. Balanced diets.

Movement in animals related to structure; the major movements in animals such as the mammal; movements involving levers in the body, i.e. muscle/skeleton; movements excluding a detailed study of skeleton; movements involving muscles alone; movements not involving muscles; non-growth movements in plants. The study of the nervous system as related to movements; co-ordination of movement; +simple nerve mechanism; elementary study of the central nervous system; reflex actions; sensory organs—tongue, nose, skin, ear, eye, care of sensory organs, sensory disorders, correction of disorders in the eye. +The endocrine glands, secretion and function dealt elementarily. +Occurrence of plant hormones.

Reproductive system of the rat and functions, including up to birth and subsequent development externally; +reproductive cycle including uterine cycle in mammals; parts and functions in a flower (dicotyledenous); pollination and pollinating mechanisms and agents (m); fertilization and development of fruits and seeds as observed externally and using a hand-lens. Types of fruits and seeds as shown by common examples. Dispersal of fruits and seeds. Germination; conditions necessary for the germination of seeds. +Dormancy.

Growth in plants including secondary thickening (m), comparison of the growth of a plant and an animal; growth movements occurring in plants. Regeneration in plants and animals leading to vegetative propagation in plants; metamorphosis as shown by Frog or Toad and insects.

Comparison of sexual reproduction with asexual reproduction. +Reproduction in a large population, variation and mutations, natural selection, physical and biotic conditions for survival, evolution; evolutionary trends leading to extinction, evolutionary trends leading to partial success; evolutionary trends leading to success; classification of plants and animals with reference to the evolutionary trends.

+The occurrence of bacteria, virus and moulds and their behaviour through groups and colonies. Sterilization and +pasteurization. +The role of bacteria, virus and moulds as disease producers; food-borne, water-borne, and air-borne; immunity. The use of bacteria and moulds including yeast in the soil, in the production of curd, cheese, water—retting fibre, curing of leather. Plants and animals of commercial importance including timber, medicinal and crop plants, corals, cattle, poultry, fish and their conservation. +Effects of radioactive fall-out on living things.

The study of soil including formation, soil types, properties, and conservation.

The study of the plants and animals in fresh water/sea shore/salt marsh habitat (m). Conditions associated with the organisms in the habitat. The study of the carbon, nitrogen and mineral cycles including their roles in the habitats. The nature of epiphytes, symbiotes, parasites, commensalism, and saprophytes exemplified by both plants and animals but without structural details of the organisms. Competition, co-operative living, insects (bees and termites). The food chain and the importance of the members in a food chain.

The above topics to be presented and studied so as to lead to a recognition of the following broad themes:

> Diversity in the animal kingdom; diversity in the plant kingdom; +Unity of life; Continuity of life; +Individuals, population and communities; Man in Nature; +Matter, energy and life.

In order that teachers in Ceylon should appreciate all that is implied by the new Biology syllabus, the Department of Examinations also prepared some specimen examination material. Readers of this book may find it of interest to see some of this material which is presented below.

Specimen Examination Questions

There will be two examination papers.

The first will be a short paper of 45 minutes based on short 'objective type' questions. This will carry 40% of total marks for answers to as many as possible of 40 questions.

The second will be of 2 hours and of the usual written type. It will carry 60% of the marks and the candidate will be required to answer 8 questions.

Examples of questions from each type of paper are given below.

Biology I (Answer as many as possible)

1. Which one of the following is not a characteristic of living things?

   (i) Response (ii) Spontaneous generation
   (iii) Growth (iv) Metabolism

7. When two organisms live together benefiting each other, their relationship is called

(i) Parasitism (ii) Saprophytism
(iii) Symbiosis (iv) Predatism

8. Which part of the hen's egg is comparable to the kernel of the coconut?

(i) Egg white (ii) Egg shell (iii) Yolk (iv) Embryo

9. Which one of the following movements occurring in plants is not effected markedly by external stimuli?

The movement of

(i) Lateral roots (ii) Lateral branches
(iii) Cytoplasm (iv) Pollen tubes

15. The process of photosynthesis is different from the other vital activities of a plant in which one of the following aspects?

(i) Water is needed for the process.
(ii) Enzymes play an important role in the process.
(iii) Inorganic substances are converted to organic nutrients.
(iv) The size of the stomata govern the rate of the process.

16. Which one of the following statements has the least bearing on the rise of fluids from the roots to the stem tips of a fifty-foot-tall plant?

(i) The cell wall is freely permeable to many kinds of molecules in solution.
(ii) In many plants a layer of meristematic tissue lies between the phloem and xylem.
(iii) The size of the stomata can be regulated by the guard cells in response to external stimuli.
(iv) Molecules of water at the surface of the leaf cells escape into the air.

19. A man lifts a heavy stone by bending his arm. A major part of the force developed in the arm comes from—

(i) Contraction of tendons and ligaments
(ii) A combination of muscular push and pull
(iii) Lengthening of muscles in the arm
(iv) Contraction of muscles in the arm

22. A variety of a flower plant was imported to Ceylon from India. Some of these migrated to the forests nearby. 10 years later these migrated plants showed a number of variations. After another 40 years there were only three well-marked types of the migrated

plants. These were now new species. These observations best illustrate:

(i) Natural selection (ii) Mutation
(iii) Hybridization (iv) Theory of inheritance of acquired characters

25. At a station X which was selected for an investigation on ancient life the fossils of the following organisms were found. Three types of ferns, two flying insects. It is very likely that the station X has been

(i) An aquatic habitat
(ii) A terrestial habitat
(iii) A salt marshy habitat
(iv) A saprophytic habitat

27. Among hundreds of a given strain of Zinnia flowers there suddenly appears a plant with markedly different characters which are passed along the progeny. This observation best illustrates

(i) Hybridization (ii) Theory of inheritance of acquired characters
(iii) Mutation (iv) None of the above

28. The slope X of a hill was covered with a sparse vegetation. The slope Y of similar gradient on the other side of the same hill was densely covered with vegetation. The valleys on either sides X and Y were flat and similar. At the end of two years during which period both sides X and Y received the same annual rainfall, the top soil of the

(i) Valley X will be rich in soil nutrients
(ii) Valley X will be poor in soil nutrients
(iii) Valley Y will be rich in soil nutrients
(iv) Valleys of both X and Y will be equally rich in soil nutrients

35. Fishermen adrift at sea may die of thirst even though there is water all around them. Why may drinking sea water in an attempt to quench thirst be disastrous?

(i) Salts in the sea water are likely to damage the wall of the stomach by eroding it
(ii) Salts are likely to pass from the body cells into the intestine to mix with the salts in the sea water
(iii) The blood which is deficient in water, will also lose more water to the intestine which contain salty sea water.
(iv) The salty sea water will pass very quickly from the intestines and to the kidney, over-burdening them

40. To plan a programme for the control of mosquitoes a person should have a knowledge of insecticides. He should also have a knowledge of the life cycle of the mosquito, its food habits, and its inter-relationships with the other organisms and the environment.

    (i) A justifiable opinion based on some facts
    (ii) An unjustifiable opinion not based on facts
    (iii) A conclusion based on inadequate evidence
    (iv) A valid conclusion based on adequate evidence

Biology II (Answer 8 questions)

1. How would you explain to a friend the following statements?
   'A plant growing in a pot for five years gained 1020 oz. in dry weight whereas the loss in dry weight of the soil was only 1 oz.'
   'Even though the contribution from the soil to dry weight is only 1 oz., yet this is very important to the plant.'

2. The following was true for an isolated forest:
   Frogs lay a large number of eggs, most of which are fertilized. The field mice bear a few young at a time. Yet the population of frogs does not rise rapidly over that of the mice.
   Discuss the significance of this in terms of the factors responsible for the maintenance of this balance.

3. Bats visit a Cadju tree regularly. Outline the ways in which the Bats and the Cadju tree are dependent on each other.
   Around the Cadju tree grows a mould which is found often together with the Bat droppings or pellets. How does this mould fit into the above ways of dependence of the tree and the Bats?

4. What is meant by respiration? Distinguish between cellular respiration and external respiration. Discuss the development of the respiratory mechanism of the Toad through its larval stages to the adult.

5. Paddy seeds are soaked in water for about 48 hours before sowing in nurseries. Describe in outline, with practical details, how you will determine the weight of water absorbed by an average paddy seed, after soaking in water for varying periods such as 2 hours; 4 hours; 8 hours; 13 hours; 24 hours; 48 hours.
   Indicate how you will demonstrate that most of the water is absorbed into a paddy seed through the micropyle.

6. Make a labelled sketch of a Salvinia plant.

   Indicate clearly by diagram an interesting modification present in the Salvinia which helps it to keep floating on the surface of water.

   You observe several Salvinia plants growing in a paddy field. Describe the methods you will adopt to control the spread of the plant.

7. A member of your household has contacted the disease tuberculosis. What preventive measures will you adopt at home to prevent the spread of the disease? Explain the resistance a person acquires by being exposed to certain diseases?

   What simple experiment will you perform at home to demonstrate that there are micro-organisms in the soil? You have unboiled milk, sterilized milk and pasteurized milk at home.

8. Give an account of the division of labour in a colony of bees. In which ways are the members in a colony of bees suited for survival. Indicate in outline how the members in a herd of deer are suited for survival.

9. Compare the processes that occur in Man and in a Coconut tree which enable us to classify both as living things. Describe one of the characteristic features among these two living things which enables us to classify Man as an animal and the Coconut tree as a plant.

10. Select three plants belonging to a single named habitat from the following:

    Eichornea, *Avicennia*, *Ipomea biloba*, *Nelumbium*, *Spinifex*, *Rhizophora*, *Pandanus*, *Vallisneria*, *Bruguiera*, *Hydrophylax maritima*, *Sonneratia*, *Pistia*.

    Describe two major adaptations in each plant which makes it particularly suited to its environment.

The Vevey Seminar Biology Syllabus

It has been pointed out elsewhere that the O.E.C.D. Seminar Report on 'New Thinking in School Biology' is a significant document to which every biology teacher could well give attention. One of the most significant features was the attempt made by Professor P. Duvigneaud, of the University of Brussels, to construct a draft syllabus in biology, based on the ideas and materials put forward to the Seminar. Anyone who reads the Seminar Report will realize that it will for long be a leading mark in the development of biological education. It will take time for all the ideas put forward to be assessed, integrated and activated. In the meantime what I have here called the 'Vevey Syllabus', drafted under the hurried conditions of a Seminar, but instinct with the excitements and new ideas of the Seminar, will prove an interesting blue-print for the future of biological education. It is produced in the original form below with the very kind permission of Professor Duvigneaud and O.E.C.D.

The proposed Syllabus is for pupils aged 12 to 18 and is divided into two parts, one for children aged 12 to 15, i.e. for all pupils, and the other for those who stay at school until the age of 18 and then in many cases go on to the University.

A. *The Basic Grounding: Living Organisms in Their Environment* (pupils aged 12 to 15)

We feel that it is important for a young pupil to start his biological education profitably by observing living things in their environment and in the community to which they belong. At this age children are usually highly observant and capable of long remembering concrete biological phenomena readily observed in the countryside or on visits to botanical gardens or zoos. They should be able to grasp the complexity of the biosphere and of man's ever-present action by observing the mosaic of biocenoses (forest, grasslands, cultivated fields, urban centres, industrial areas) which make up the local landscape.

During these excursions special emphasis should be laid on the main agricultural products of the region, their uses and yields (notion of productivity); samples will be taken of crops and other material for closer study in the school biology laboratory, and plants transferred to the experimental garden which should be attached. A square metre of forest or living grassland can also be preserved for a whole year in a suitably watered asbestos tank, and pupils enabled to watch the development of phenophases due to the different periodicities of the species concerned.

The teaching given in the classroom, and also as far as possible out of doors, will be based on the observations described above and on familiar items such as bread, meat, and coal; the outlines of the physiology and ethology of living organisms will thus be revealed. Photosynthesis for example can be illustrated from observations and simple and interesting experiments (see Section III).

A good idea would be to choose a number of biocenoses that could be visited several times during the year (forest, grassland, a pond, marshland, perhaps a peat-bog).

Pupils would be shown that these comprise various populations of the same species which are usually intermingled to form communities of different species. Observation of populations already allows a provisional definition to be made of species, i.e. more or less similar individuals in which similarity is repeated from generation to generation; much can of course be learnt from observation of this; and I believe it is very important to train the mind from the outset to detect similarities as well as to observe differences, however slight.

Having thus been introduced to the notion of species, pupils would learn to recognize and name plants and animals, the most studious of them using a simple treatise on fauna or flora for this purpose.

Populations and communities could then be studied in the selected biocenoses and in the general local environment. Pupils would on the one hand be shown their structure (in space and in time), degree of aggregation and variability, and on the other by means of measurements with simple apparatus would study the factors which limit their extension.

It would seem desirable at this point to introduce a few notions of pedology, with field study of several types of soil in order to show the economic importance of plant–soil relationships.

These ecological and pedological observations would enable the key notions of isolation and natural selection of the fittest to be deduced.

Study of the inhabitants of a forest is particularly attractive; simple techniques for extracting fauna from soils, catching insects, birds and mammals, isolating bacteria, actinomycetes and lower fungi, will make clear to pupils while allowing for other plants and animals which are easier to observe, including tree consumers and dead wood decomposers, most of the animal and vegetal systematic groups. Hence the notion of the diversity of the plant and animal kingdom can be grasped.

This is the place for study of the main animal and plant groups with the essential details of their anatomy and physiology; the main viewpoint will be that of the biological cycle with special stress on the mode of reproduction—man must be one of the main items of this study. One can then, in as vivid a way as possible, explain the great laws of genetics which enable us to understand heredity. Enough well-designed and illustrative models are available nowadays to enable pupils who have only an elementary knowledge of chemistry to understand the functioning of the nucleic acids, enzymatic systems and chlorophyll.

The history of the earth's population and especially the evolution of the principal animals and various human species can be fitted in here; a good teacher can fire the enthusiasm of even the youngest pupils for this subject.

The central position of man in the modern world having been established, his responsibility for the development of the biosphere can be emphasized and respect of the environment and one's fellows, the conservation of resources and protection of nature can be discussed. The important subject of health can here be dealt with, in addition to elementary notions of genetics.

B. *A Biology Course for the Modern Citizen* (pupils aged 16 to 18)

We will now attempt to draw up a concise plan of a more detailed course for older pupils (16 to 18 years) who have already received the basic grounding described in Section A.

The syllabus proposed is a vast one and may seem utopian in the present state of affairs when so little time is usually available for the teaching of biology.

Although in fact a syllabus of a university course in biology, only the broad outlines essential for the intellectual education of the modern citizen would be taught.

At the very least a selection should be made among the topics that we propose. The actual order of subjects would depend on circumstances, but pupils should be constantly reminded that living matter (mainly nuclear acids, ATP and enzymatic proteins) is integrated at levels of growing complexity, the main ones being cell, tissue, organ, individual, population (collection of individuals of the same species), community (collection of individuals of different species), ecosystem, and the biosphere, of which man forms an integral part.

THE CELL

After examining under the microscope cells of various origins taken from selected ecosystems two fundamental structural elements may be considered, i.e. genetic material and metabolic machinery, whose combined activity regulates the functioning of the cells and gives rise to its most important properties: uniform reproduction and mutation.

Genetic material

Chemical formulas presented in graphic form (helicoidal steps, moulds and comb-like figures, etc.), as in many articles in the *Scientific American* or in the B.S.C.S. brochures, henceforth provide a fairly ready explanation of the nucleic acids and their particular properties such as self-reproduction and the heterocatalytic function leading to protein synthesis. Observations and a few simple experiments, for example with the tobacco mosaic virus, can be made to illustrate this topic. This is also the place to study mitosis and the properties of chromosomes, and the definition of the gene as a unit of function.

A large number of very simple and varied experiments can show the existence and functioning of enzymes (e.g. action of amalyase on starch and of mycrosin on glucosides containing sulphur).

The oxydation and reduction enzymes of the potato are also very easy to deal with.

Yeasts cultivated side by side under aerobic and anaerobic conditions provide a ready introduction to the subject of anabolism and catabolism and also show the great importance of a microscopic fungus in the economy of the planet (bread, various alcoholic beverages).

In the same way well-grounded pupils can be taught the main aspects of glycolysis, the Krebs cycle and fermentation reactions (cases to remember are the butyric fermentation, revealed by smell, and the lactic fermentation, ascertained through taste (sauerkraut, yogourt)).

Photosynthesis of plant cells

Observation under the microscope of chloroplast cells, accompanied by chromatographic separation of pigments and simple experiments (iodine treatment of leaves partially masked, release of oxygen under the action of different coloured lights, etc.) will provide a key lesson on the all-important phenomenon of photosynthesis.

Stress should be laid on the formation of starch as the basis of both animal and human diet and on the release of oxygen as the basis of animal and human respiration.

Suitably prepared pupils can be shown, through use of colourful diagrams and formulas, the chemical mechanisms of photosynthesis (photophosphorylation, Calvin cycle).

Protein synthesis

A few comments should be made on protein synthesis (enzymes) and of DNA as the carrier of information to these proteins. Here again graphic models are available, which can be changed as molecular biology makes further progress.

It is not too soon to envisage simple laboratory experiments on bacteria and fungi (some already exist in 'The Laboratory' series of the B.S.C.S.) in order to provide vivid illustrations of the genetic mechanisms reviewed above.

THE INDIVIDUAL (the organism)

Organisms are either uni- or multicellular. As the latter are better known and do not need a microscope, they will be studied first, and unicellular organism afterwards.

A brief description (possibly completed with field nature study or visits to botanical gardens and zoos) reveals the more familiar forms of higher plant and animal life to be associations of cells developed from the same zygote which are differentiated in tissues and organs (distinction between germen and soma; potential immortality of the germen; death = consequences of the advantages of multicellular life).

The functioning of the organs and that of the entire organism (physiology) will be considered, together with the characteristic correlation phenomena. This is also the place for study of embryological growth.

The functioning of a higher plant must be studied very carefully.

This is the time to carry out the observations, practical work and experiments which though classical are always topical and easy to perform (photosynthesis, respiration, tropism, germination).

The mineral nutrition of plants, which can easily be explained experimentally with higher plants (the Sachs experiment) or with the *Aspergillus niger* (Raulin experiment) will be discussed in the context of fertilizers and the growing of more food. The role of growth and florescence hormones of plants will be explained.

With regard to animals at least one oviparous chordate and one mammal should be chosen, and the development of their ontogeny should be shown—formation of embryonic cell layers and of the principal organs (use of film documentaries). At the same time, when carrying out practical work, dissections will be made to show the location, form and inter-relationship of organs. This will introduce physiology and functioning of each system will be described. Care must be taken to avoid giving the impression that an organism is merely the juxtaposition of autonomous anatomo-physiological systems, by insisting on their interdependence, e.g. the role of the liver as the ancillary gland of the digestive tube, the complementarity of circulation and respiration and, above all, the notion of hormonal correlation. Pupils will thus learn how the human body is constructed, that it functions like the body of any other mammal and, especially, how its behaviour is largely controlled by hormones. Disease can then be defined as the result of physiological disorders due to various kinds of aggression or to erroneous diet. Further reference would then have to be made to individual health, pupils being taught moderation in the use of medicines, and the principles of rational nutrition. In conclusion a brief account will be given of the present state of biological knowledge with regard to ageing and the health conditions of old age.

THE POPULATION

The following main points can be dealt with in particular by field observations:

1. Structure

Various types of aggregation of individuals in nature. Sociability. Isolation. Animal societies (bees, termites, etc.).

2. Autecology

Distribution in relation to environment. Study of climatic, microclimatic (topography), edaphic, and biotic factors. Field observations, measurements with various instruments, which according to circumstances may be simple or advanced. Setting up of fixed or mobile biological stations. Ecological and geographic isolation.

3. Social behaviour of animals, group effects—the special nature of man

4. Population genetics and the mechanisms of neo-Darwinian evolution
   - (*a*) Mutations (see Part B). Macroscopic study of a few easily observed mutations (Drosophila; plants cultivated in the school garden or in pots; Oenothera, Mirabilis, Draba, etc.). The DNA model can be used to explain the mechanism of mutation at the level of the molecule. Mutations at the level of the chromosome. Polyploids. Induced mutations. Dominant and recessive characters.
   - (*b*) Genetic systems for field study: apomictic (notion of clone) and amphimictic populations; self-fertilization and cross-fertilization. Pollination of flowers by insects (observations and captures); phenomena of cleistogomy, heterostyly, etc., phenomena of incompatibility (fruit trees). Genetic isolation.
   - (*c*) To explain fertilization: meiosis and gametogenesis. Determination of sex.
   - (*d*) Genetic consequences of the mode of sexual reproduction: variability of populations.
     - —Field surveys (diagrams and curves) of qualitative and quantitative characters (weight of seeds, number of ligules of a capitulum, shape of acorns, etc.).
     - —Experimental laboratory studies of micro-organisms.
     - —The theoretical explanation: Mendel's laws. The notion of the gene as a unit of recombination; occurrence of recessive characters sometimes formed much earlier by mutation; chromosome factor maps; practical work on Drosophila.
     - —Interspecific hybrids.

(*e*) Neo-Darwinian evolution. The relative contributions of heredity and environment to the formation of a character; notion of ecotypes (illustrated by the technique of transplanting in an experimental garden); distinction between phenotypes and genotypes, readily demonstrated by simple experiments (*Bacillus prodigiosus*, *Primula sinensis*). From the variability of populations, which is due to mutations or hybridization, and from the special distribution according to different kinds of environment (natural selection, isolation) the mechanisms of neo-Darwinian evolution can be deduced; the example of *Spartina townsendii* and especially of wheat, which offers material for an excellent lesson based on collections of wheat seeds or even on hybridization experiments made in the school garden; convergence of the natural events that have led to the emergence of wheat: combination of chance (the agronomic miracle), hybridization (contribution of genome D of *Aegilops squarrosa*), polyploidy (crossing sterility barriers by duplication of chromosomes) and human intelligence (selection by man of worthwhile varieties); the recent synthesis of MacFadden and Sears.

This leads to the notion of species in the bio-systematic sense and hence to a consideration of systematics.

Systematics (see section I)

A study of the classification of animals and plants, together with theoretical considerations, may now appropriately be undertaken: phylogenetic classification with horizontal levels of evolution and vertical evolutionary phyla. It is easy, for example, to develop modern principles for an interesting classification of Angiospermae based partly on floral biology. Study of the principal groups will be resumed with more thorough account of their biological cycle. Study of pedofauna of a forest soil or of plankton in a pool is very rewarding in this respect. Pupils should be taught to use suitable floras and faunas so that they can identify plants and animals themselves.*

Bioclimatology and adaptation

Important climatic factors induce adaptations. Some of these are morphological; the convergence of life forms allows us to define formations (deciduous forest, steppe, moor, coniferous forest, savanna, heath, etc.) distribution in belt or additional zones of vegetation. The term 'descriptive biology' is often used at this point, but what we are really dealing with here are the results of experiments on a vast scale, spanning entire geological periods and conducted by nature itself.

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* The ability to define and identify plants and animals is a frequent aspiration of pupils in secondary schools, and a must for those who will later be studying populations, communities and ecosystems.

These plant formations and the adapted animal life they contain (biomes) can be used to show evolution in action. They are best observed by field trips in the mountains.

For the pupils of some West European schools who make a long educational trip abroad each year, the excursion from Nice to Authion via Peira Cava and Turin is especially rewarding. Halophile plants are equally interesting objects of study. The didactic usefulness of National Parks becomes obvious at this point.

History of the earth's population

Next one can go on to deal with the history of the earth's population and the broad evolution of plants and animals (palaeontology, radiation of reptiles). The origin of life may be indicated here according to the hypothesis of Danviliers (presence of CO_2) or of Oparin-Urey (absence of CO_2). The reconstruction of the primitive organic world by the Miller's experiment is instructive to relate, also, biogeography provides an approach to the history of continents.

If there is a peat-bog nearby, simple pollen analysis will give some idea of recent history of terrestrial ecosystem.

THE COMMUNITIES

The following topics can be studied:

1. Links of dependence. Parasitism and symbiosis. Saprophytes (e.g. consumers of oak).
2. Phytosociology. Structure of associations. Ecological groups. Characteristic species. Indicator species (calcicoles, halophytes, silicicoles).
3. Periodicity. Biomass. Competition and succession (phenophases), the living forest.
   Use of maps and surveys for developing an area.
4. Biomes. Major types of biomes which make up the biosphere. Aspect due to the life-forms of the dominant plants, large animals. Characteristic large animals. Principal crops.

THE ECOSYSTEM

The definition of an ecosystem (collection of living beings, of their alimentary and chorological links and of their relationships of all kinds with the abiotic environment) can be deduced from what has gone before and can best be taught out of doors in a forest or other chosen formation.

More theoretically, but using vivid diagrams, one can then explain the bases of the science of ecosystems: flow of solar energy; major biogeochemical cycles (C, H_2O, M, P, S, etc.); trophic chains and networks; the efficacy of ecosystems will be shown through biomass —and especially productivity pyramids. Primary and secondary productivity, which are so important for understanding the position of man in the biosphere, will be explained. The description of concrete examples of an ecosystem can be achieved through more detailed study of one or more of the following: a pool, the ocean, soil, or forest.

The ocean is a fine subject which lends itself to simple treatment and whose interest lies in the hope which it offers for the future of mankind.

Study of the soil is one of the most rewarding in lessons of all sorts: by extracting soil fauna and isolating soil flora, pupils can observe the profusion of living organisms of all kinds which take part in the formation and decomposition of humus. Nitrogen fixation, antibiotics, beneficial action of earthworms, problems of the rhizosphere, etc., are subjects which can be combined with general considerations regarding soil fertility.

The usefulness of lessons on soils results from the enormous importance assumed nowadays by pedology. Experiments in Belgium (e.g. the 'Jeunesses Scientifiques') show that this science, comprising both field and laboratory work, is readily accessible to young people.

THE BIOSPHERE

Lessons on the biosphere should show clearly man's position as an integral part of his environment; for men with responsibility, a knowledge of the biosphere based on notions of general ecology is now indispensable.

The dominance of life over the environment rests on the diversity and co-ordination of biological phenomena.

Man must respect this diversity and avoid upsetting biological balances. He must acquire understanding and respect for all other living creatures which surround him and for other human beings in particular.

The need should also be stressed for increased productivity of the biosphere until Man has everywhere become wise and civilized enough to limit population growth himself; this will provide a means of showing the enormous importance in the near future of scientific research on plant and animal biology and on agriculture.

The following topics could be expounded in greater detail, as in 'Documentation 23'.*

The biosphere, the source of man's food

1. Productivity of the biosphere.
   Production capacity of the biosphere and the quantity of foods thus actually offered to man: edible plants, cattle, milk, eggs, fish and game.
2. Man's food needs and world hunger.
3. The progress of medicine and hygiene and the world population explosion.
4. The decline in food reserves.
   Erosion and exhaustion of soils, the general drying up of continents. Biological pests and diseases which destroy food before consumption. Pollution of the air, land, and water (including the effect of radio-active waste).
5. The spectre of Malthus and the hope of mankind.
   The solution lies in a large number of measures and expedients which all require more research both in fundamental and applied biology. Conservation of natural resources. Development of arid and inter-tropical zones. The stamping out of parasites and disease. Agricultural progress. The progress of genetics and biosystematics; the obtaining of new races or species of plants and better adapted animals with higher yields. The progress of ecology. Better applications of the resources of seas and oceans; use of deep-sea diving for scientific ends; the enormous interest of oceanography. Maximum use of plant production, which is ten times more productive than herbivorous animals; better use of plant proteins. Use of forests and especially of wood for food purposes. Cryptogamic and synthetic foods.

The biosphere, source of well-being and prosperity

Beverages, stimulants, and perfumes; textiles, hides, and skins. Wood and cellulose. Paper as the base of intellectual production.

Beauty of scenery and human health.

Protection of nature: integral reserves, study reserves, tourist reserves, national parks.

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* The various points that can be dealt with when studying the ecosystem are expounded in the brochure 'Documentation 23' of the Belgian Ministry of National Education and Culture. (Any teacher wishing to obtain this should ask his own Ministry of Education to obtain it for him.)

APPENDIX J

SOURCES OF BIOLOGICAL MATERIAL FOR USE IN THE SCHOOL LABORATORY

Many teachers have indicated their need for a list of addresses from which supplies are obtainable, especially relating to sources outside their own country. The following is a short list prepared to meet this need. Inevitably it is too short, incomplete and open to question because so many names have been left out. It is however a start which can be supplemented by checking the advertisements in the journals devoted to science and science teaching.

Aimer Products Ltd. (Semi-micro chem. 'portable' lab.)	56/58 Rochester Place, Camden Rd., London, N.W.1, England
Baird & Tatlock Ltd. (General Supplies)	Chadwell Heath, Essex, England
C. Baker Instruments Ltd. (Patholette Microscope, converts to projector)	Metron Works, Purley Way, Croydon, Surrey, England
R. J. Beck Ltd.	Bushey Mill Lane, Watford, Hertfordshire, England
Carolina Biological Supply Co. (Biological supplies)	Elon College, N.C., U.S.A.
Cenco S.A. (General apparatus)	Konijnenberg 40, Breda, Netherland
Cooke, Troughton & Simms (Microscopes)	Haxby Road, York, England
Coronet Instructional Films Inc. (Films)	65E Southwater St., Chicago 1, Ill., U.S.A.
Denoyer-Geppert Co. (General)	5235 Ravenswood Avenue, Chicago, Ill., U.S.A.
T. Dryden Ltd. (Micro-organic)	Landore, Swansea, S. Wales
Eastman Kodak Co. (All photographic needs)	343 State St., Rochester 4, N.Y., U.S.A.
Edmund Scientific Co. (Optical etc. fossils, models)	Barrington, N.J., U.S.A.
Educators Progress Service 'Educators Guide to Free Science Materials' Curriculum Films Filmstrips	Randolph, Wisconsin, U.S.A.
Edwards High Vacuum (School vacuum app.)	Manor Royal, Crawley, Sussex, England
Electrano (Sci. Inst.) Ltd.	Penqarreg, Ystrad Meurig, Cardiganshire, S. Wales
Encyclopaedia Britannica Films Inc. (Films)	1150 Wilmette Avenue, Willmette, Ill., U.S.A.
Eureka Scientific Co. Ltd. (Semi-micro-inorganic)	192/198 Illford Lane, Ilford, Essex, England

Fisher Scientific Supply Co. (General Science supplies)	717 Forbes St., Pittsburg, Pa., U.S.A.
Fisons Scientific Apparatus Ltd. (Glassware)	Loughborough, Leicestershire, England
Flatters and Garnett Ltd. (General)	309 Oxford Rd., Manchester 13, England
Gallenkamp (General)	Technico House, Sun St., London, E.C.2, England
General Biological Supply Co. (Biological supplies)	8200 South Hoyne Avenue, Chicago 20, Ill., U.S.A.
T. Gerrard & Co. Ltd.	46/48 Pentonville Rd., London, N.1, England.
Gillett and Sibert Ltd. (Microscope and projectors)	417, Battersea Park Rd., London, S.W.11, England
Graf-Apsco Co. (Microscopes)	5868 Broadway, Chicago 26, Ill., U.S.A.
Griffin & George (General Science supplies)	Ealing Road, Alperton, Wembley, Middlesex, England
G. T. Gurr Ltd. (Stains)	136/140 New Kings Rd., London, S.W.6, England
Hopkin and Williams Ltd. (Chemicals)	Freshwater Rd., Chadwell Heath, Essex, England
Keystone View Co. (Films)	Meadville, Pa., U.S.A.
La Pine Scientific Co. (General)	6001 South Knox Avenue, Chicago 29, Ill. U.S.A.
Learning Central Inc. (General)	53 Bank St., Princeton, N.J., U.S.A.
Learning Materials Inc. (Teaching aids)	100E Ohio St., Chicago 11, Ill., U.S.A.
Los Angeles Biological Laboratories (Biological supplies)	2977 W. 14 St., Los Angeles 6, Cal., U.S.A.
Macalaster Scientific Corporation (Education Division) (Science teaching aids and apparatus)	253 Norfolk St., Cambridge 39, Mass., U.S.A.
Marian Ray (Filmstrips)	36 Villiers Avenue, Surbiton, Surrey, England
McGraw-Hill Text Films (Films)	330 West 42nd St., New York 36, N.Y., U.S.A.
Merck and Co. (Stains and general)	Rahway, N.J., U.S.A.
Modern Learning Aids (Teaching aids)	3 East 54th St., New York 22, N.Y., U.S.A.
W. B. Nicholson Ltd.	Thornliebank, Glasgow, Scotland
Charles Perry & Co. Ltd.	34/36 Monsell Rd., Finsbury Park, London, N.14, England
W. R. Prior & Co. Ltd. (Students' microscopes)	London Rd., Bishop's Stortford, Hertfordshire, England
Phywe Aktiengesellschaft (Sci. instruments)	Gottingen, P.O. Box 665, W. Germany
Pysor Britex Ltd. (Micro-projectors, Russian microscopes)	329 High Holborn, London, W.C.1, England
Science Electronics (Semi-Micro-Electron)	15/16 Newman St., London, W.1, England
Science Materials Centre Inc. (General)	200E 23 St., New York 10, N.Y., U.S.A.
Scientific Instrument Ltd. (Four-in-One Microscope)	439 London Rd., Boxmoor, Hertfordshire, England

Scientific Teaching Apparatus Ltd. (Teaching aids, etc.)	27/37 Broadwick St., London, W.1, England
Technicolor Ltd.	
Turtox General Biological Supply House Inc. (General and specimens)	6200 South Hayne Avenue, Chicago 20, Ill., U.S.A.
Ward's Natural Science Establishment (Biological supplies)	P.O. Box 1712, Rochester 3, N.Y., U.S.A.
Welch Scientific Co. (General supplies)	1515N Sedgwick St., Chicago 10, Ill., U.S.A.
Woods Hole Marine Biological Laboratory (Biological specimens)	Supply Depot, Woods Hole, Mass., U.S.A.
Diana Wyllie Ltd. (Filmstrips)	36 Villiers Avenue, Surbiton, Surrey, England

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